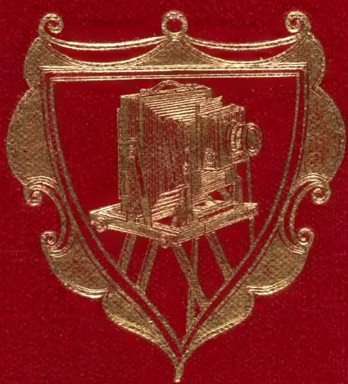
PHOTOGRAPHY OF TO-DAY



H. CHAPMAN JONES

[illegible]

A

PHOTOGRAPHY OF TO-DAY

John H. Gear.

A RAINBOW FROM AN AUTOCHROME.

The Autochrome itself is a three-colour photograph. It is here copied by the three-colour typographic process. This picture is therefore a three-colour reproduction of a three-colour photograph.

PHOTOGRAPHY OF TO-DAY

A POPULAR ACCOUNT OF THE ORIGIN, PROGRESS AND LATEST DISCOVERIES IN THE PHOTOGRAPHIC ART, TOLD IN NON-TECHNICAL LANGUAGE

By

H. CHAPMAN JONES, F.I.C., F.C.S., F.R.P.S.

President of the Royal Photographic Society; Lecturer on Photography in the Imperial College of Science and Technology, South Kensington

With [illegible] Illustrations & Diagrams

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1913

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AUTHOR'S NOTE

I HAVE to thank Mr. John H. Gear for allowing his beautiful autochrome, "The Rainbow," to be reproduced as the frontispiece, and I have to thank also Messrs. J. H. Dallmeyer, Ltd., Dr. H. H. Hoffert, H.M.I., Mr. E. O. Hoppé, Mr. F. V. T. Lee, *The Psychological Review*, Mr. Edgar Scamell, Mr. George Scamell, Mr. Arthur E. Smith, The Thornton-Pickard Manufacturing Co. Ltd., and Professor R. W. Wood, for the characteristic photographs that they have so kindly contributed, and in some cases for the valuable information that they have freely placed at my disposal.

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PHOTOGRAPHY OF TO-DAY

CHAPTER I

LIGHT, ITS NATURE AND EFFECTS

As light is the active agent in photography, it will be well if we endeavour to find out something about its nature and what it is able to do, before we begin the consideration of our specific subject. It has been suggested that such knowledge is unnecessary, because those that paint do not trouble themselves much, if at all, about the chemistry of their pigments or the manufacture of their brushes. Indeed, some would go further and argue that such knowledge is likely to be detrimental, because it tends to divert the thoughts of the worker into uncongenial channels and so to prevent the concentration of his mind upon his picture making, which is the chief matter that should occupy his attention.

But although "pictures" may be made by photographic means, the art of the painter is not really comparable to the art of the photographer. The photographer does not take a pencil of light and draw with it as the "artist" draws with his pencils, but he so regulates his apparatus that the light itself shall do the drawing. The two cases are fundamentally different. The most important characteristic of photography is that it is so largely automatic. And besides this, if from the present moment all "picture" making by means of photography were to cease, photo-

graphy would still continue to be practised as one of the most useful of the applied sciences.

It is sometimes argued that it is not necessary to understand the principles upon which photography is founded, because it is sufficient to be provided with a kodak or other such camera, and to follow the instructions, to get quite acceptable pictures. It is equally true that one only needs a barrel organ or a musical box and to follow the instructions in order to get quite acceptable music. And the use of a kodak gives its possessor less insight into photography than the use of a musical box can into the subject and practice of music, so far as it is possible to compare the two.

Therefore without further apology we will proceed to discover as we may some ideas as to what light is and how it acts. If you stand on one side of a darkened room looking towards some one on the other side who strikes a match, you will observe that the moment he strikes the match light is produced. The light has by some means moved across the room, entered your eyes, and produced an effect there which has enabled you to recognise it. It may not at first be obvious that the light has really travelled across the room in this case, but the only alternative is that something has gone out from your eyes to the match, that is the origin of the light, and has come into contact with it. Something not of the nature of an arrow shot from a bow, but of a long arm or feeler which remains in connection with the eye while it reaches as far as the match. It is certain that there has been communication between the two, and communication is never possible between two things at a distance unless a connection of some sort is established between them. There is ample evidence that nothing is projected from the eye, and accepting this as proved, the simple experiment described demonstrates that light moves or travels away from its source. It can be proved also that it travels in all directions

from its source as a centre, because if you move from corner to corner of the room, if you stand upon a chair and look downwards or lie on the floor and look upwards, so long as your eyes are directed towards the match, you recognise the existence of the light.

In an equally simple way we can illustrate, if we cannot prove, the nature of this movement. The kind of movement with which we are most familiar is that of a railway train, or the bullet fired from a gun. Here the thing itself travels along, and even if we could not see it, we should have proof that it does really move by its coming into forceable contact with anything that stands in its way. A soldier does not see the bullet that wounds him, but he knows perfectly well that it has come from a distance and that it has come to him. In the same way the air travels from one place to another when the wind blows, and the breath from our lungs travels to the candle flame when we blow it out.

But there is movement of quite a different kind. Here the thing itself does not travel, but only a motion passes from one place to another. Take two or three yards of rather thick string or cord that is not unduly stiff, as new string or twine is likely to be, tie it into a loop at one end, and hang the string by the loop on a hook or nail at the top of a door, or in a similar convenient position. Next take hold of the other end and walk backwards until the cord hangs slightly curved, that is, do not pull it too tight. Now rapidly move up and down again the end of the string that you hold, or, as one might say, give it a jerk. This movement that you impart to one end of the string will pass along the string, every part of which will in turn move up and down, and if your vision is quick enough you will see a hump, or raised part, travel along the string. Indeed you will easily so manage, that when this up and down movement that you started at one end of the string gets to the other end, the loop on the hook,

this will move up with such marked effect that it will jump right off the hook. This method of getting the looped end of a rope to jump off a hook or post is commonly practised by men at the docks, by maids with their clothes lines, and in many similar cases. Here the rope or string or cable does not travel along, it is only the movement that travels.

It appears to be necessarily true that all methods of communication between objects at a distance from each other is due to one or other of these two kinds of movement. Either a material object travels from one to the other, or a movement travels. In the case of the string it is obvious that the movement travels along the string. If the string were cut, the movement or the jerk imparted to the one end of it could not pass over the space between the cut ends, however small it might happen to be. However forcibly the one end might be jerked, the portion that hangs on the hook would remain perfectly still. The movement of one part of the string cannot impart movement to another part unless it is in actual contact with it. Therefore we see that when a movement travels there must be something to move, something that it can travel along, and this something must be continuous. One object cannot affect another at a distance unless there is some continuous connection between them, some substance along which the effect or the movement can travel without interruption.[1]

When a drum is struck, the drumhead is driven suddenly inwards, and this movement is comparable to the jerk given to the end of the string just referred to. We know that the effect of the stroke travels to us, because

[1] The force of gravity, by which is meant the attraction that all substances have for each other and which causes them as far as possible to move towards each other, as when a stone falls to the earth, may appear to be an exception to this general statement ; but this is a force that we can neither start nor stop nor alter in any way, and therefore essentially different from the forces that mmediately concern us.

we have in the ear an arrangement that can respond to such a movement, and give us the sensation that we call sound. We are concerned only with the fact that this effect (sound) travels from the drum to us. It is clear that the jerk given to the drumhead does not produce an effect similar to the result of the jerk given to a bullet when the charge behind it explodes, because there is nothing comparable to the bullet that passes from the drum to us. Here again it is the movement that travels and not the substance. We could see the movement travel along the string, but we cannot see the movement that travels from the drum, because in this case it is the air that moves and through which the movement travels, and the air is invisible. If there were no air between us and the drum, the sound could not travel to us, any more than the movement of the string could pass over an interval between the separated ends of the string when it was cut. It is not easy to remove the air between ourselves and a drum to test this statement, but if a bell is caused to ring in a closed chamber from which the air can be removed, as in the receiver of an air pump, as the air is pumped out the sound gets feebler and feebler.

If you can find a continuous long iron rail, such as may be in a public park, and get some one to strike it with a stone or a pocket knife or something of the kind, at a considerable distance from you while you press your ear upon the rail, you will hear the sound of the striking twice, although the rail has been struck only once. That is because the sound travels through the iron bar as well as through the air, and as it travels along iron about fifteen times more quickly than through air, the movement caused by the percussion gets to you first along the iron bar, and afterwards through the air. This shows that the particular movement to which our ears are sensitive (sound), although it travels faster than the movement travelled along the string, takes a perceptible time to travel

even so small a distance as twenty or thirty yards. If a workman is watched from a distance of about four hundred yards, the sound of each stroke of his hammer will not get to you until more than a second after you see that he has made the stroke. After seeing lightning we have to wait for the thunder, although they are both produced at the same time, because the sound travels so much more slowly than the light.

We will return now to our first experiment with the match. The light travelled across the room, and we may ask which of the two kinds of movement took place? Was it that some substance, like a bullet from a gun, travelled from the match to our eyes, or was it only a movement that travelled? It used to be considered that actual particles, very small particles, were shot out. It is quite easy to get particles so small as to be invisible even when the utmost power of the microscope is at our disposal, so that it is not so great a strain on our imagination as it might at first be thought to be, to suppose that actual particles might pass into our eyes without injuring them. But this theory was found altogether insufficient to account for the phenomena shown by light, phenomena that we cannot discuss here, while if we suppose that the travelling of light is simply the travelling of a movement, these difficulties disappear.

The question that immediately concerns us from a photographic point of view, is that if it is only a movement that travels, what is it that moves? We know that light can travel to us not only from such small distances as across a room, but from the sun, which is more than ninety millions of miles away, and even from stars that are many thousands of times as far off as the sun. It is not conceivable that the atmosphere that envelops the earth can extend so far, for it gets rapidly rarer as we ascend even a few miles from the surface of the earth. And besides, the removal of air to the utmost extent possible from a vessel

in no way impedes the passage of light through it. Light therefore is not like sound, a movement of the air or other ponderable material, but it is a movement of something, and very little is known about the nature of the medium that moves when light travels through it. It is called the luminiferous ether, and supposed to be a kind of refined atmosphere that permeates all space and all substances.

We have seen that light travels; it must therefore take time to travel. If a cardboard screen is held in front of a lighted taper on the other side of the room, the moment the screen is removed you will see that the light has travelled across the room, because if you are looking towards it, it will have entered your eye and you will see it, or you will see that it shines upon the opposite wall. You will find it impossible to detect any interval between the removal of the screen and the arrival of the light at the far side of the largest room, or even at the greatest distance out of doors that you can make available for the experiment. But if instead of one screen there are several screens, and these are arranged round the edge of a wheel, so that they may be very quickly moved by the revolution of the wheel, it is possible to prove that light takes a measurable time to travel over a comparatively short distance.

The wheel with the screens round its edge resembles a cog-wheel, as shown in Fig. 1, and a beam of light can be sent through the space between one cog and the next, and then by means of a mirror about five miles away sent back to the wheel. The mirror may be arranged so that the reflected beam will pass through the same opening that it shone through at first. A person who looks through the opening in the direction of the mirror will see that the light is reflected back to him, and the little practical difficulty of his head getting between the source of light and the wheel and so preventing the light from shining in the required direction, could easily be overcome

by means that we need not trouble about, as we are concerned only with the principle of the experiment. The observer, then, sees that the light is reflected back to him. If the wheel is slowly rotated the light will be alternately stopped by each cog and allowed to pass as each space between the cogs comes into position. The light that each space allows to pass will travel to the mirror and back again so quickly that the wheel will have moved an imperceptible distance by the time the light has returned, and it will still shine through the same opening that allowed it to pass to the mirror. But if the wheel is turned with speed

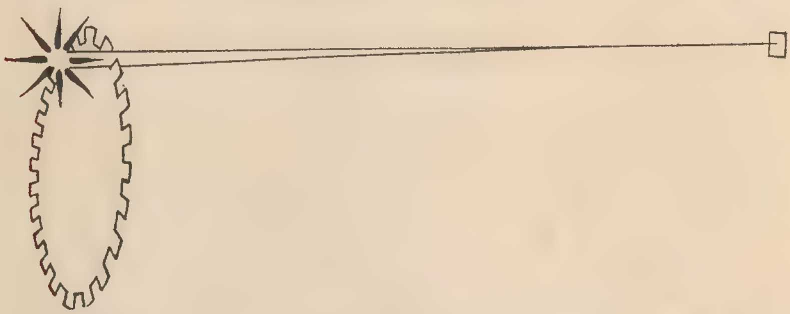


FIG. 1.—An apparatus that serves to demonstrate the fact that light takes an appreciable time to travel a few miles.

enough, the observer behind the wheel will see no light coming from the mirror, although everything else, except the rapid rotation of the wheel, is exactly as before. This is because by the time the light reflected by the mirror has got back to the wheel, the wheel will have moved sufficiently to bring a cog into the place of the notch through which the light passed on its way to the mirror, and as each reflected beam of light falls upon an opaque cog, the observer cannot see any light. By revolving the wheel more quickly still, the reflected light will become visible again, because each flash will now fall upon the next notch to that through which it passed at first. It is only necessary to know the distance from the wheel to the mirror, for this

doubled will give the distance that each flash of light has travelled, the speed at which the wheel revolves, and the number of its cogs, to calculate how long the light takes to make the journey of these few miles.

There are other methods by which the rate at which light travels has been measured, and they all agree in showing that it moves through the air a distance of between one hundred and eighty and one hundred and ninety thousand miles in one second. This has important bearings upon photographic work. The most obvious, perhaps, is that we can never see or photograph an object as that object *is*, but only as it *was* when the light that reaches us started from the object. This difference is practically negligible, a very minute fraction of a second, so far as terrestrial distances are concerned, but as it takes light about eight and a third minutes to travel from the sun to the earth, we can never photograph the sun as it is, but only as it was a little more than eight minutes before we take the photograph. And some of the stars are so far off, that it takes light hundreds or even thousands of years to travel from them to us. A disturbance or change in such a star that is seen or photographed to-day, must have taken place long ago, in some cases considerably before the commencement of the Christian era. That particular movement of the luminiferous ether caused by the change or disturbance has been travelling ever since, much as the ripples on the surface of a lake caused by the touch of a bird continue to move towards the shore after the bird has left the water and perhaps gone out of sight. Just as our records of the sun are always more than eight minutes late, if we may so express it, so our knowledge of distant stars is always a few hundreds or thousands of years after time, and we have no means of knowing what has happened in the interval, for no movement known is more rapid than that of light.

Thus light is a travelling movement, and as it concerns us so intimately we want to know something about the

character of the movement. Without discussing the various possible kinds of travelling movements, we will turn back to our first experiment with the string. It is clear that the movement travels along the string, but a moment's thought will show that the movement of each part of the string is in a direction across the line of the string. If the string were horizontal we might say that each part of it in turn moves up and down while the movement itself passes along. Fig. 2 shows how the elevated portion of the string, or the hump, travels along while the various parts of the string move transversely. The small arrows show the direction in which the parts of the string that they are in contact with are moving, and the dotted

FIG. 2.—A travelling movement.

line shows the position of the hump at a little later stage of its travel. This is the character of the movement when light travels, and we shall subsequently see that it is of fundamental importance to us in the consideration of colour in connection with photography.

When light travels there is never a single disturbance as shown in the figure, but a succession of them. This may be illustrated, if the string is long enough, by a succession of jerks, and then a succession of humps will pass along the string. Fig. 3 shows this "wave motion." There are three possible kinds of variation in the character of these waves with which we have to do, and it is by the control of these, and the control of the total quantity or bulk of movement (if this expression is allowed), that we can make light our servant. The first and most important of these is the "wave length," that is the distance from one

crest to the next, or from the top of one hump to the top of the adjacent hump. But the wave length itself cannot immediately influence either our eye or the photographic plate, because as we have stated before it is only that which comes into actual contact with either the eye or the plate that can affect it. All light, whatever its wave length, travels

FIG. 3.—Wave motion.

at the same speed under the same conditions, so that the shorter the waves are the greater must be the number of them included in any given distance; as the parent and the child trotting along by his side go at the same rate, but the little one with shorter legs takes shorter steps, and makes up for this by taking them more rapidly. In the experiment with the string each jerk made a hump or wave

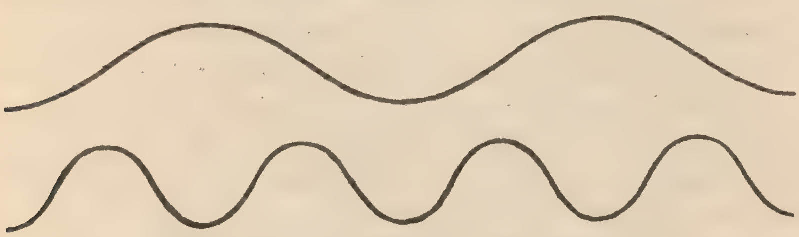


FIG. 4.—Waves of different "wave lengths."

that travelled along the string. If by any means these jerks could be given at twice the rate, the conditions being such that the rate of movement remains the same, the waves produced would be half the length of the original waves, as shown in Fig. 4. It is clear that twice the number of the shorter waves as of the longer waves will arrive at the end of the string in the same time. Now, although the action on neither the eye nor the plate can be directly

affected by the length of the waves, it is affected by the rapidity with which the jerks or impulses are delivered, and this as we see depends upon the wave length. The wave length is the cause of the "frequency" of the impulses, and the "frequency" is the immediate cause of the character of the effect produced. If the frequency is such that the light appears red, then a greater frequency (caused by a shorter wave length) will give light of an orange colour, and by further increasing the frequency (shortening the wave length) we shall have in order yellow, green, blue, and violet light.

In Fig. 5 the comparative wave lengths of light travel-

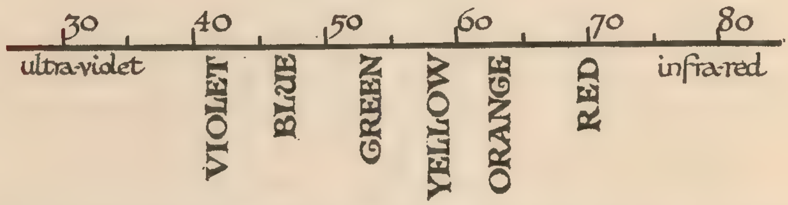


FIG. 5.—Colours as produced by light of different wave lengths. Illustration of a spectrum.

ling in air are set out on a regular scale and the colours are indicated, and whenever light is by any means separated into its constituents or spread out as shown here the result is called a "spectrum." It will be noticed in the figure that there are waves too long and waves too short to affect our eyes, for the organs of sight are of strictly limited powers. When light (if it can be so called) that consists of waves longer than the red or shorter than the violet enters our eyes we do not know it, because our eyes are not affected by such light. Indeed, if we were to represent the whole range of light waves so far as they are known by extending Fig. 5 very considerably indeed both to the right and to the left, we should get some idea of the small proportion of the whole that can affect our eyes, or in other words, enable us to see. It is as if we had the whole range

of notes as represented by the keyboard of a piano, but were only able to hear the notes produced by about one octave, our ears being so made that while this octave produced sound in them, we were deaf to all the notes higher and lower. We shall find subsequently that light affects, or produces changes in, many things besides our eyes, and there seems to be no reason why just that part of the whole range that affects our eyes and so enables us to see should be the exact part that affects other things. As a matter of fact it is not so, and we can go further and say that probably no two substances are exactly alike in this matter.

The second circumstance that affects the character of the movement that we call light, is the amplitude of the vibrations. If the moving parts of the luminiferous ether move to a slight extent only, the movement is sluggish and the effect is feeble, but if they move to a greater distance to and fro, the wave becomes higher, the movement more vigorous, and the effect correspondingly greater or more intense.

The third circumstance is the plane in which the vibration takes place. In the experiment with the string, the vibration took place in a vertical plane because we jerked the end of the string up and down. But we might have jerked it from side to side, and the vibration would then have been in a horizontal plane, or it might have been caused to take place in any other plane between these two. In the case of ordinary light, the vibrations take place in all planes. Light vibrating in one plane only is said to be "polarised," but this does not concern us.

And now it is desirable that the reader should endeavour to get as clear a conception as possible of what ordinary light is, a clear picture in his mind of what takes place when ordinary light travels along and impinges upon or bombards any surface, whether that is the retina of the eye, the sensitive plate, or a ripening plum, or a

fading curtain, or any other of the objects or substances on the face of the earth to which it can gain access. Imagine a thin beam or pencil of light as might be seen illuminating the dust of the air if the sun were shining brightly through a small round hole in the shutter of an otherwise darkened room. The various portions of the luminiferous ether are moving to and fro across the beam with an enormous velocity as the waves pass along it, the waves are of an innumerable variety of lengths, and they are moving across the ray in all possible planes. Some will interfere with others, for a portion of even the luminiferous ether cannot move in two different directions at the same time. We can hardly liken it to an infinite number of writhing snakes of very different sizes, nor to a great number of strings jerked like that used as in the first experiment, because these things are so large and the movements connected with light are so exceedingly small, and these things move so slowly while in light the movements are of inconceivable rapidity. In all this apparent confusion, every movement is strictly and absolutely regular, the confusion is in our minds only, and is the result of the impossibility of picturing to ourselves a mixture of such a vast variety of simultaneous movements.

The next thing that we have to try to imagine is what change, if any, is light likely to produce in a substance upon which it falls. It may rebound, somewhat after the manner of a ball that is thrown at a wall, and produce no recognisable effect upon the object that it strikes; a large proportion of it may pass through and again produce no apparent effect, for light passes through glass, quartz, diamond, and many other substances. But in innumerable cases a change is produced by the action of light, and those changes are of all kinds.

We have seen that light is nothing more than a movement, and when it comes into contact with a substance it tends to impart a movement to it. If, in our first experi-

ment with the string, the string had been tied tightly to the nail and the nail were a little loose in its hole, the movement that passed along the string would have jerked the nail and might have jerked it altogether out of its hole. Then the travelling movement would have been communicated to the nail so as to produce a very obvious change in its position with regard to the wall. Light excites or renders active substances that were at first comparatively inactive. It may, by affecting the ether that permeates the substance, put a condition of strain upon that substance so that it becomes unstable and therefore changes into a different state that is more stable under the new conditions. Speaking generally, light acts upon substances by urging them into activity, and the result of the activity will be whatever change may be possible under the circumstances. We cannot say in general terms that light tends to produce this or that particular kind of change, it is more true to say that any kind of change may result from its stimulating influence.

Changes are classified into two groups, physical and chemical. A physical change takes place when a substance is altered in form but remains the same substance, while in a chemical change the substance itself is changed into one or more other substances. Wood may be cut up into sawdust—that is a physical change because it is still wood; but if the wood is burned—that is a chemical change, for the result of the burning is charcoal or ash, carbonic acid gas and water, and these are not wood. Meat may be minced, it may be chewed ever so well, and it still remains the same substance; but when it is digested there is a chemical change, for it is altered into other substances. Diamond, graphite, and charcoal, although so different in their characters, the diamond transparent and hard, the graphite opaque and soft, differ only in a physical sense. Chemically they are one and the same substance, carbon, for if an equal weight of each is combined (by

burning it) with oxygen, it is found that in each case exactly the same weight of oxygen is required and exactly the same weight of carbonic acid is produced. If therefore we by any means change graphite into diamond we effect a physical change, for we have the same substance, carbon, but in a different form.

Light can effect physical changes. If a solution of sulphur in bisulphide of carbon is exposed to light, the sulphur is changed into a different form which is not soluble in the liquid and therefore falls to the bottom of the vessel as a powder. This insoluble sulphur is whitish, while ordinary sulphur is yellow. If ordinary white phosphorus is exposed to light it is changed into red phosphorus, which is different from the original not only in colour, but in solubility, volatility, and oxidisability. It may be safely kept as a dry powder, while ordinary phosphorus has to be kept under water to prevent it from igniting. Selenium is a substance very similar to sulphur in many of its properties. When obtained in the crystalline form it allows a current of electricity to pass through it, though it offers a very great resistance to the current when the selenium is in the dark. But when light shines upon it, its resistance is reduced very greatly indeed, so that under otherwise similar conditions it allows of the passage of a much larger current. When the light is cut off the resistance becomes great again. Practical advantage has been taken of this effect of light in order to transmit photographs by means of the telegraph—to this we shall subsequently refer—and also in Bell's photophone, which serves to change variations in the brightness of a light into variations in an electric current, and these by means of the telephone are converted into sound. We are not concerned with these instruments, but only with the fact that selenium in the light is different from selenium in the dark, although it remains selenium and nothing else all the time. One other example. Cinnabar is red, and it is

a compound of mercury and sulphur. The same compound of mercury and sulphur exists also as a black substance, and if the red compound is put into an alkaline liquid and exposed to light it changes to the black variety. Many other examples of such changes might be given, but the illustrations show that light is able to produce various kinds of physical change. We have seen that it can effect changes in solubility, volatility, oxidisability, electrical conducting power, crystalline form, and colour, the substance changed remaining in all cases of exactly the same composition, that is, no material is either added to it or withdrawn from it.

We will now look at a few cases in which light produces a more thorough change, altering the composition of the substance, so that after the change it is no longer the same substance. If the two gases hydrogen and chlorine are mixed in a glass vessel and kept in the dark, the mixture remains a mixture. If the vessel is brought into a moderate light, the two elements will gradually combine and produce hydrochloric acid gas. The molecules of a gas are always moving, and when light shines upon this mixture the movement becomes more vigorous, or it may be that a different kind of movement is brought about, and we see the result of this stimulation in the combination of the gases. If a more intense light, such as that of burning magnesium, is caused to shine upon the mixture, the disturbance will be correspondingly greater and the combination will take place with explosive violence. The light here causes combination. But if the hydrochloric acid gas produced is dissolved in water and the solution is put in the window, the disturbance caused by the light in this case will result in the slow decomposition of the hydrochloric acid and some of the chlorine will be liberated. This is not a case of the simple separation of the hydrogen and the chlorine, because the hydrogen at the same time combines with oxygen of the air to form

water; but still the chlorine and the hydrogen are separated by the action of light, while in the former case they were caused to combine. If the white compound of chlorine and silver is exposed to light, the compound becomes dark and some of the chlorine separates from it. If this experiment is done in a closed glass tube so that none of the separated chlorine gas can escape, and the tube after exposure is put away in the dark, the chlorine will gradually recombine with the dark residue and the original white compound will be reproduced. So that the disturbing action of the light in this case forces the chlorine off the compound against, so to speak, its inclination, and it recombines as soon as the disturbing force is withdrawn. It was noticed that the change brought about in selenium ceased as soon as the light was withdrawn, the selenium returning to its original condition. We shall find subsequently some changes caused by light that will continue to progress after the light is withdrawn, and others that will cease altogether when the light leaves them. And there is no object here in multiplying examples, as our only aim is to point out that light is only a movement, that it acts only as a disturbing force, and that the result of the disturbance may be of any kind according to the circumstances.

Sometimes light is supposed to have a special tendency to bleach coloured substances. It certainly does bleach coloured curtains, carpets, wall papers, and many other things. But on the other hand the green colouring matter of the leaves of trees, the grass, and vegetable growth in general, is produced by the action of light. Chloride of silver is white and is darkened by light, and innumerable examples might be given of both bleaching and colour production by the action of light. The simple fact is that light produces changes, and it is often the case that the product of the change is different, so far as colour is concerned, from the original substance.

Light, Its Nature and Effects

It is not correct to consider that light has any inherent tendency to produce changes of any one particular kind. It is a disturbing or stimulating force, and the result of its action will depend upon all the circumstances of the case.

CHAPTER II

THE CONTROL OF LIGHT

MAN has controlled light, and so to a certain extent adapted it for his use, from the very earliest times. When the dweller in tents pushed open his tent door to let in the morning light, and when he shaded his eyes with his hand in order to see more clearly at a distance, he modified the light so that it should the better serve his purpose. If the tent door had remained closed there would have been some light inside, and if his eyes had not been shaded the distant object would still have been visible, but by letting in more light in the first case and excluding some in the second, he so controlled the light as to increase the visibility of the objects that he wished to see.

This method of controlling light leads us to the simplest kind of photography. Photographs are records made by light, and in every case where light has caused an obvious difference in the parts of an object exposed to its influence when these are compared with the parts shaded from it, a photograph has been produced. If a blade of grass is pulled up, root and all, it will be seen that the part that was above the ground is green and that the part that has been buried and in the dark is not green. This is a photographic record of how much was exposed to light and how much was underground. We bear upon our bodies a photographic record of the clothes we wear. Our hands and faces are darker than the covered parts, and in the summer when the light is the most active, the face gets sunburnt while the forehead remains of a lighter colour because it is shaded by the hat. The pattern of lace worn

on a lady's neck may be clearly visible when the lace is removed, if she has been unduly exposed to sunshine. White paint in the shade turns yellow, while in the light it remains of its original colour. The darker patch behind a bolt knob is a photographic record of the existence of that knob. And many other examples might be given of photographic records produced, as we say, accidentally, and often to our annoyance and inconvenience.

There is a common idea that photography has to do with a comparatively small number of substances, if not entirely with a few compounds of silver. So far as the number is restricted, it is only a matter of adaptability to certain definite ends. A photograph can be made on any surface that is affected by light. A pattern may be cut out in a suitable material and placed, for example, on the sunward side of an apple that is ripening. In due time the apple will have a photograph on it, because the sunshine will be unable to produce its effect upon those parts that are shielded from its influence. Devices may be produced in a similar way by means of stencil plates or cut-out patterns upon innumerable other surfaces. In these cases there are only two tones or degrees of darkness, the one where the light has had free access to the surface and the other on those parts that have been covered over; but if instead of a pattern cut out of an opaque material we employ a glass plate with a deposit on it of various degrees of transparency, a shaded design may be produced. In this case the light is controlled as to its intensity, or the extent of its action, and not merely as to the place where it shall act.

The method just described is the simplest, crudest, and most obvious kind of photography. The impression is always of the same size as the original, and the original must be of such a character that it can be placed upon and in close contact with the sensitive surface. But we often want a copy to be larger or smaller than the object itself,

even when this is flat and of a character suitable for giving a contact copy. And besides, we want pictures or records of all sorts of things, such for example as buildings, machines, persons, and landscapes, that are not flat and could not by any means be made to lie upon or against a sensitive surface, to say nothing of the impossibility of treating them so on account of their size.

In these cases it is necessary to produce an image of the object, getting the image of the required size, and to bring this, instead of the object itself, into contact with the sensitive surface. The image must be a real image, that is, one that can be received upon a screen after the manner in which an optical (or magic) lantern gives an image on the sheet. The image that we see of ourselves in a looking-glass is not a real image, it is only a virtual (or apparent) image; it cannot be brought into contact with a surface because it has no existence, except in the sense that it is an appearance.

All objects that we can see are visible because of the light that they give out and that travels from them to the eye that sees them. It is obvious that light comes from visible things if they are self-luminous, like the sun or a candle flame, and it is just as true of objects that shine by reflected light, such as the moon, the planets, and all the common things with which we have to do. The problem that we have now to consider is, how can this light be controlled so as to cause it to give the image that we want. The great bulk of light that emanates from an object of considerable size we cannot consider *en masse*, as the attempt to do so would lead to indescribable confusion. And this is not only impossible but unnecessary, because if we understand how the light from a very small part of the object can be manipulated so as to produce a correspondingly small part of the image, we shall have the information that we want, as it will only be necessary to apply the same considerations to every other small part of

the object in order to understand the production of the complete image. We may imagine the object to be divided up in much the same manner as the design on a tessellated pavement with very small tiles; then in order to produce an image the light that comes from each tile must be made to produce a tiny spot of light on the surface that is to receive the image, each spot of light in its proper place in relationship to the others. We will consider two such small parts, and in order to facilitate the experiments

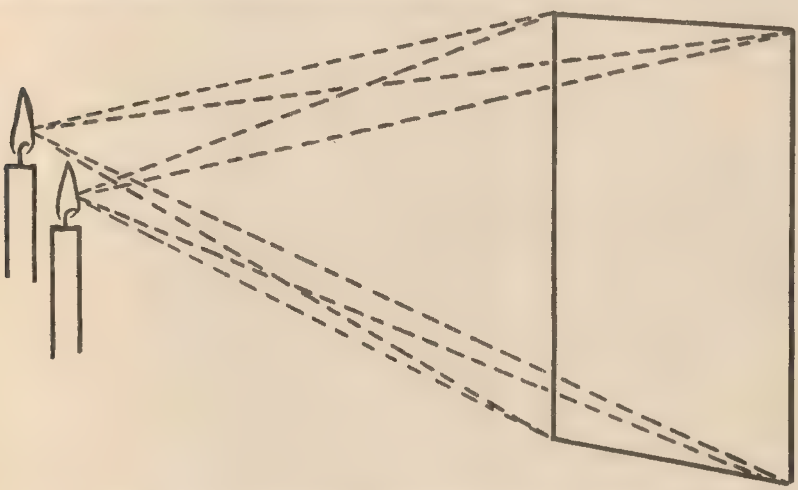


FIG. 6.—Two candles shining upon a sheet of cardboard.

we will take two candle flames, for these will perfectly well stand for them.

Take two lighted candles and set them up three or four inches apart, and support a piece of white cardboard, a foot square or rather larger, at a distance of about eighteen inches from them, as in Fig. 6. On darkening the room, it will be seen that each flame shines all over the card and there is no suggestion on it of an image of the flames. Now take another card about the same size as the first, prick a hole in the middle of it with a large pin, and hold it half-way between the two flames and the first card. This shields the light from the card first set up, but each

flame shines through the pinhole and produces a patch of light upon it (Fig. 7). Here then we have at least the elements of an image. If we bring a third candle near to the others, it also will give its patch of light, and if we were able to go further and make a pattern with candle flames, as pyrotechnists make flaming and glowing devices with their fireworks, we should get an image of the pattern on the screen. As a matter of fact, a simple pinhole may be quite serviceable for some practical photographic purposes, giving a useful image of general objects.

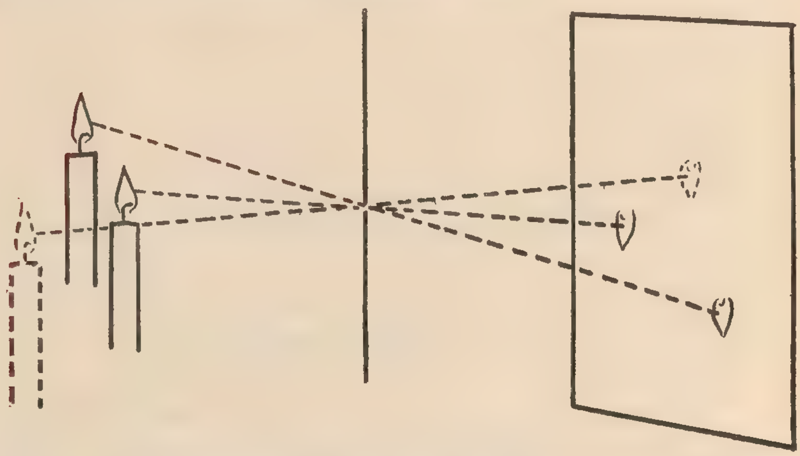


FIG. 7.—A pinhole screen between the candles and the cardboard causes an image to be produced.

Now examine carefully the spots of light obtained on the cardboard, bearing in mind that each should be of the same shape as the flame that produced it, though upside down. That it should really be upside down may be demonstrated by raising one of the candles and observing that as it is lifted up the spot of light that its flame has produced moves downwards. The light travels in a straight line, and if you like to represent its path by a knitting-needle, you might thrust it through the pinhole and see how that, when one end of the needle was raised the other end fell, like a see-saw with the pinhole for its support.

But what we specially want to notice is, that although the flames are bright the images are very dull, and that although the flames have decisive and sharp edges, the edges of the patches of light that stand for the flames on the cardboard are diffuse, perhaps so much so that it is difficult at first to recognise the shapes of the flames in the patches of light. We have an image, but it is dull and fuzzy instead of being bright and sharp as we want it to be. It is dull merely because the hole is so small that very little light can get through it. Make the hole larger and the image will be brighter, but it will be even further removed from sharpness. You may make another hole close to the first pinhole; this will add its own quota of light, but as the light travels in a straight line, this second hole will give its own image by the side of the image given by the first hole, partly overlapping it, and so the confusion will be increased. The pinhole is the first step in the getting of an image-forming apparatus, but we should be poorly off if it could not be improved upon.

Take one candle with the white card as before, but in the intermediate card make three pinholes in a row with a distance of about two inches between each and the next. The candle flame now gives three spots of light or images of the flame on the screen because the light travels in a straight line from the flame through each hole and onwards to the white card. If we could bring these three images together, so that they were all at exactly the same place on the card, we should have one image but of triple brightness. Now the only way by which this is possible is by bending at least two of the rays. This is the essence of the whole art of getting a bright and a sharp image, namely, *bending the rays of light that otherwise would go astray, in such a manner that they shall all work together in the production of one image.* In the present experiment this can be done with two small pieces of looking-glass

held in the positions shown in Fig. 8. You will find it rather difficult to hold both the mirrors still enough to get the three spots of light exactly superposed, but the principle of the concentration of the light will be clear.

Now imagine a fourth pinhole and a third mirror, and go on in imagination, for you cannot do it experimentally, making more holes and putting more mirrors to bend the rays that pass through them, and you can see in your mind's eye the spot of light getting brighter and brighter. We saw before that a smaller hole gave a sharper image

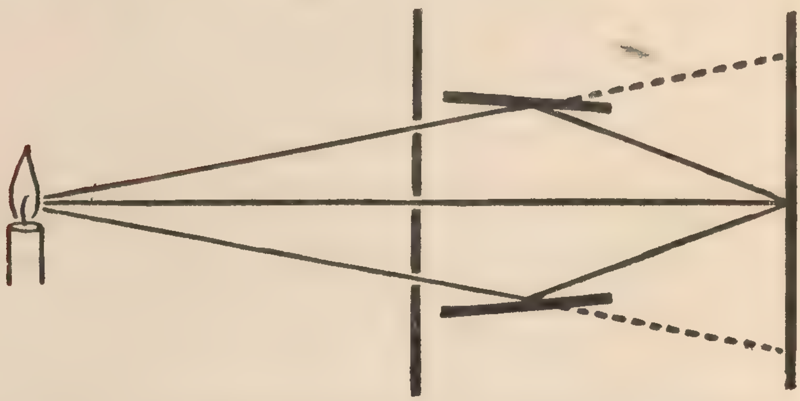


FIG. 8.—A brighter image produced by superposing three separate images.

though a duller one, so fancy now that all these holes are very small, each with its mirror, and we have not only a bright image but a sharp image. If now these small holes were very close together the mirrors would have to be very small and each set at its proper angle; it is but another step to imagine no space at all between the holes, and the tiny mirrors all joined to form one continuous surface of proper curvature to gather all the light that a mirror or reflector of the given size and position could gather and concentrate to form the image.

By this means it would be possible to get a sharp and bright image, but such a mirror would be very troublesome to make, and could not be more than a mere ring,

for otherwise it would come between the flame and the screen on which the image is desired and so cut off the light altogether. A curved mirror of a practical kind for giving an image is illustrated in Fig. 9, and the full lines

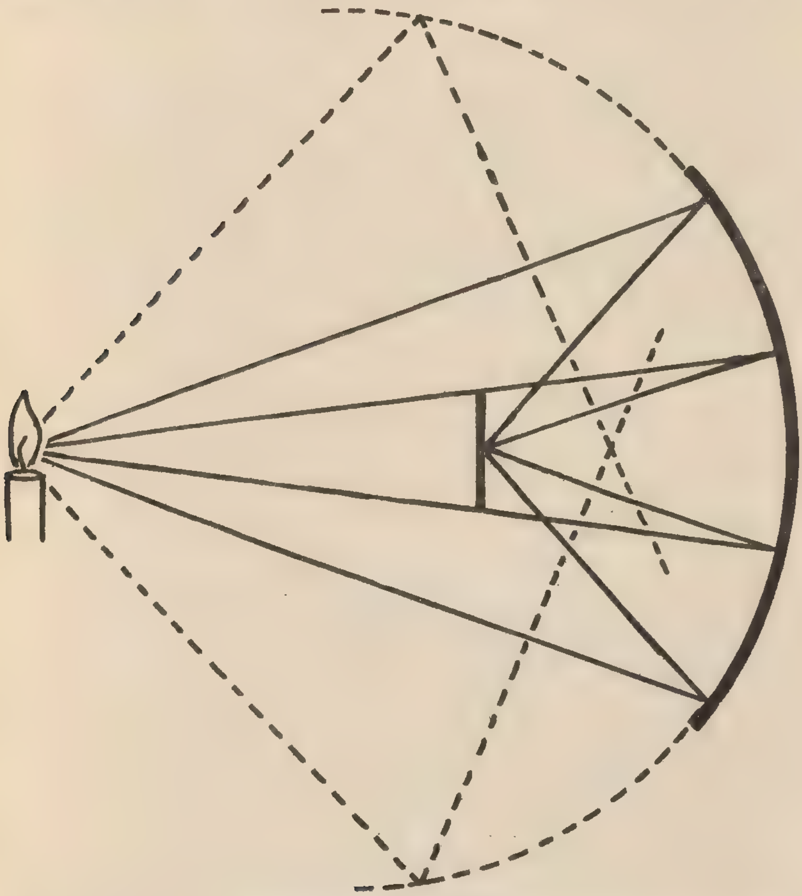


FIG. 9.—An image produced by a mirror, showing also the error due to its spherical curvature.

drawn from the candle flame show how the light that proceeds from it is reflected and concentrated upon the small screen between the flame and the mirror. Here also the effective part of the mirror is ring-shaped, because the screen put to receive the image shields the central part of the mirror from the light. In the

quite early days of practical photography mirrors were sometimes used for portraiture, but they were found inconvenient for this very reason, and also because much stray or uncontrolled light gained access to the apparatus, which of course had to open at the end directed towards the person being photographed. For astronomical purposes mirrors offer some special advantages. Dr. A. A. Common made some three feet in diameter and one five feet in diameter. All the light from a single star that falls upon such a mirror is concentrated upon a single point comparable in size to a pinhole, and the brightness of this point or image may be millions of times greater than the spot of light that a simple pinhole would give.

The large mirrors just referred to were not exactly spherical in curvature. The unsuitability of a truly spherical mirror when it extends to more than a small part of the sphere of which it may be considered to be a portion, is shown by the dotted lines in Fig. 9. The light reflected from its margins would not be sent towards the point where it is wanted to help to make the image bright. This fault or "aberration" is called "spherical aberration," because it is the inevitable result of using a spherical surface for this purpose. It gradually increases from the centre of the mirror towards its margins, but if the mirror curve is shallow, being only a small part of the whole sphere, the effect of this aberration is slight and an image of a useful degree of sharpness may be obtained.

We saw in the first chapter that ordinary light consists of a mixture of many kinds of light, light of many different colours, as in the rainbow, if we regard the visual effects of its components, or of many different wave lengths if we regard it in the more fundamental way and irrespective of our eyes. One great advantage of mirrors as image-forming instruments is that they affect all these different components of light in exactly the same way. There is no separation of them, for the same law of reflection

A Beech Tree in the New Forest

applies equally to all. It is the same law that comes into play when an india-rubber ball is thrown upon the pavement, or when a billiard ball rebounds from the cushion of the table (providing that no "side" or twist or spinning movement is given to the ball), namely, that the angle at which it falls or strikes is also the angle of the rebound, a law that probably needs no further elucidation.

We have already seen that in order to get a bright image it is necessary to bend some of the divergent rays of light, so that they also may be brought to contribute to the formation of the image. We have seen how these rays may be bent by reflection, but there is another and quite different way by which this bending may be accomplished. The path pursued by a ray or "pencil" of light may be bent by introducing into its path a different medium from that in which it is travelling. Of course all media used for this purpose must be transparent or the light would not pass through them. Of the more common we have, besides the air, water, glass of numerous varieties, and many mineral substances such as rock-crystal or quartz, Iceland spar, fluor spar, mica, the diamond, &c.

When a ray of light impinges perpendicularly upon the surface of a second medium, as when it passes from air into water or glass, the direction of its path is not changed, and this statement holds good whether the surface of the second medium is flat or curved, as shown in Fig. 10. The shaded part may be taken to represent a slab of glass. But if the direction of the ray is not perpendicular to the surface of the second medium, then the direction of the path of the ray is changed, the ray becomes bent, and the bending so produced is called, in optical language, "refraction," to distinguish it from the bending of the ray by reflection. If the second medium is denser than the first, as in the case of the passage of the ray from air into glass

as shown by the thick line in Fig. 11, the path that the ray pursues is bent towards a line drawn perpendicularly to

FIG. 10.—Light passing from one medium to another continues in a straight line when it impinges perpendicularly upon the separating surface.

the surface. In passing from the denser to the rarer medium the ray is bent from the perpendicular, and, if the two surfaces of the glass are parallel, this second

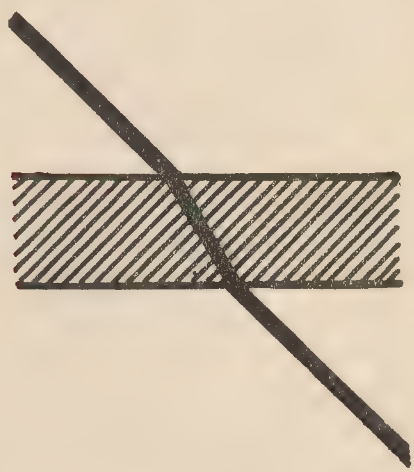


FIG. 11.—If the path of the light is not perpendicular to the separating surface, its direction is always changed—the light is "refracted."

refraction is exactly equal to the first, but being in an opposite direction the path of the emergent ray is parallel to the ray's path before entering the glass; it is in the

same direction, but it is shifted a little sideways, as shown in Fig. 11.

Therefore the net result of passing the light obliquely through the slab of glass with parallel sides is no permanent bending or refraction of the ray, because what is done at one surface is undone at the other. But when the two surfaces of the glass are not parallel the result is different. Exactly the same laws apply, and the reader can easily work out the result for himself, but the effect is always that the direction of the path of the ray is changed. This gives us the second method of bending

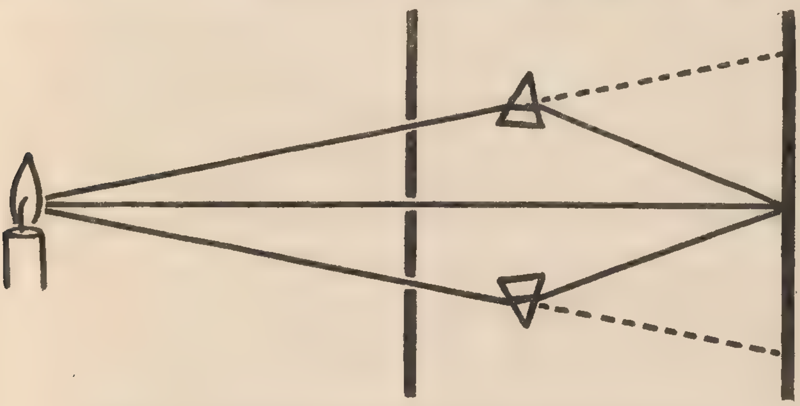


FIG. 12.—Three images superposed by means of refraction.

divergent rays and concentrating them upon any required spot. The candle flame and the screen with its three pinholes, as in Fig. 8, are shown again in Fig. 12, but this time the two outer pencils of light are bent by causing them to pass through wedge-shaped pieces of glass, and the three spots of light are superposed, just as when the mirrors were used. A wedge-shaped piece of glass or other similar transparent material is called a "prism."

In exactly the same way as in the case of the mirrors, we may imagine that the pinholes in the screen are increased greatly in number and that each has its appropriate prism to bend the ray of light as required, and we

may suppose that the holes are made smaller to get a sharper image. But in this case we can go further than when using the mirrors, and imagine the small holes all over the screen, or all over a large circular patch in the middle of it, each with its own little prism. If, now, instead of all these tiny prisms a single piece of glass, with a surface that is continuously curved as indicated necessary by the prisms, is placed in position, the card with its multitude of pinholes that we have produced in our imagination may be removed, and all the light that falls upon the curved glass will go to form the image. The image will be bright if the curved glass, or "lens," is large, because of the amount of light brought to its formation, and the image will be sharper than when only the pinhole was used, because we may regard the sharpness as the equivalent of a much smaller pinhole. Moreover the apparatus is convenient, because it is possible to enclose all the space between the lens and the screen that receives the image and so to shut out stray light. Thus we have realised another important step in the production of an apparatus that will give a good, useful image, for we have got the image both brighter and sharper than that produced by the simple pinhole, and we have obtained these advantages by means of an apparatus that does not suffer from the difficulty of having to put the screen that receives the image between the candle and the apparatus that produces the image.

If only the lens would do exactly what we have just represented it as doing, it would be perfect. Unfortunately this is not the case, for a single piece of glass, even though it were shaped without any error as we have imagined it to be, would suffer from several imperfections with regard to image formation; it could never bring all the light that emanates from each small portion of the object to form a similar small portion of the image. There are methods by which these imperfections can be reduced in amount,

but none of them can ever be entirely got rid of, even though no limit were placed upon the cost or the complexity of the final product of the optician's skill. It is not possible to make any lens, however complex, that will be at its best under all conditions. It is customary therefore to perfect lenses in different directions according to the uses for which they are intended. It is not fair to the optician to take a lens made for one specific purpose and apply it to another, any more than it would be fair to a tool-maker to complain that his tools were not efficient

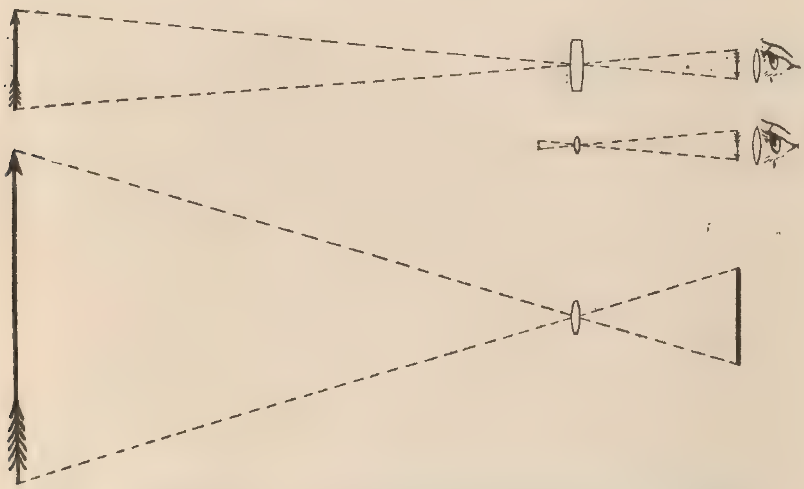


FIG. 13.—Illustrates the essential difference between image-forming instruments—the telescope, the microscope, the ordinary camera.

when they had failed in the doing of work for which they were never intended. In concluding this chapter we will endeavour to get some idea of the different kinds of work that lenses are required for in photography.

The three chief classes of instruments in which images are produced by lenses may be indicated by the telescope, the microscope, and the photographic camera of the usual kind. The essential characteristics of these three instruments are illustrated diagrammatically and compared in Fig. 13. In the telescope a comparatively small image is

produced of a distant object, in the microscope a comparatively large image is produced of a near and small object, and in both these cases the image is examined through another lens that magnifies it. The only part of the image that is really needed is the central part that the eye can see through the lens provided. Here, therefore, the extent of the utilised portion of the image is very small, generally less and often very much less than an inch in diameter, and the image within that area must be so well defined that it will bear magnification.

But in the case of the ordinary camera the extent of the plate that the image is required to cover is often very large. The most popular of the small sizes is the "quarter-plate," and in order to cover this the image produced must be at least five and a half inches in diameter, while for a "half-plate" it must be eight inches in diameter, and practically the lens must give a larger extent of image than this to allow of adjustment. These are but small plates such as amateurs most often use, and no definite limit can be set to the size of plate that may be required for commercial purposes. This extent of required image is the essential characteristic required of lenses in general photographic practice. Here we take the image as it is. We do not magnify it as in the telescope and the microscope, and therefore the optician directs his attention to the getting of a large area of image good as a whole, rather than a very small area of image with such exquisite exactness in its details that it will stand much magnification before it shows its imperfections.

There is one other matter that we want in a lens, and that is size. It may be regarded as a window, and the larger it is the more light it will admit. With twice the amount of light, a given amount of work can be done by it in half the time, and this saving of time is often of the very first importance. It means that in instantaneous work the period of the exposure may be halved, and that the moving

object may therefore be moving twice as fast without causing any more detriment to the picture by its movement. It is a little advantage in having one's portrait taken to have to be still for only two seconds instead of four, but the rapidity of the lens is a matter of perhaps greater importance to the trade worker than to any one else. If the time required for the exposure is halved, it means that the operator can do more work in the day. Or if for any reason this should not be so, it certainly means that more work can be got from one camera in the day, and that therefore in a large establishment fewer cameras are necessary. And fewer cameras need less accommodation, less artificial light when that is used, and thus a general saving in workshop expenses. Large and quick working lenses, therefore, are not to be regarded as fads for the eccentric or luxuries for the rich, for they may prove very profitable even if they are very costly.

CHAPTER III

LENSES, OLD AND NEW

WE have seen in a general way how lenses act in the production of images. We have seen too that a perfect lens would be one that would collect all the light that it could according to its size from each point of the object, and concentrate that light upon the corresponding point in the image. There are several distinct reasons why no lens made of one piece of glass can do this, however perfect the workmanship of it may be. The action of the lens in each separate way that makes it impossible to realise the perfect image that we want is called an "aberration." An aberration may be regarded as a fault so far as the photographer is concerned, but it is not essentially a fault at all, because it is of the nature of the lens to behave as it does.

The aberrations of lenses are not easy matters to make clear in non-technical language, but to pass them over on this account would lay the author open to the charge of neglecting one of the principal branches of the subject with which this volume deals. For it is only by the reduction of these aberrations that lenses can be improved, and each step in advance diminishes those restrictions that a practical worker with lenses always feels to limit his endeavours. It has already been pointed out how a lens of large area, by giving a bright image, not only saves time, but enables work to be done that would be impossible with a slower lens. But to make a lens of larger diameter without lessening its powers in other ways, necessitates a more thorough correction of its aberrations, if its power to give a well-defined image is to be maintained.

There is no aberration that exists in the simplest lens, such as a spectacle lens, that can ever be eliminated. In most cases the elimination of an aberration is theoretically impossible with the various glasses that are now available, but even if it were theoretically possible to get quite rid of an aberration, the fact that human work is never perfect would set a limit to the degree of perfection attainable. When, therefore, a lens is stated to be "corrected," when it is stated to be "achromatic" (that is, without producing colour effects in the image), when it is stated to be "rectilinear" (that is, giving lines in the image that should be straight, without curvature), it means no more than that the maker has set himself to correct these aberrations, and not that he has absolutely succeeded in doing so. It is much the same when we speak of a good boy; we never mean a perfectly good boy, and it would be absurd to reserve the expression until such an impossibility was discovered.

The various aberrations of lenses all exist together, and there are refinements and subdivisions of them that we cannot pretend to approach. The complication of the character of the changes effected by the lens upon the light passing through it is past all powers of description or imagination, but by considering the more important aberrations in their simplest forms and one at a time, it should not be difficult to get a general idea of the nature of each of them.

The field of a lens is the place where the image of a distant view is produced. It is desirable that the field be flat, for one reason because the surface of the sensitive plate upon which the image is required to be received is flat. If the field is not flat, then the image and the plate cannot be made to coincide except at a small part, and where they do not coincide the image must be "out of focus." This is illustrated in Fig. 14, in which the field is shown as curved, and the dotted lines represent a flat

plate, on which only a small part of the image can be in focus wherever it is placed. The general tendency is for the field of the lens to be concave as shown, and it has actually been proposed to use concave plates like clock glasses, when this curvature introduces special difficulties. For general work such plates would be quite unpractical,

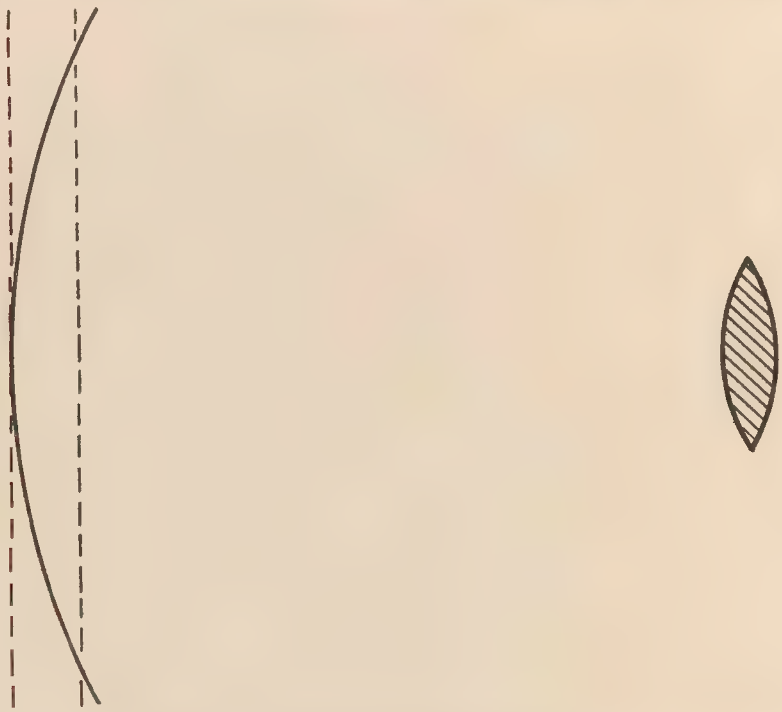


FIG. 14.—A lens with a curved field cannot give the image on a flat plate.

and indeed they would introduce other and perhaps more troublesome irregularities. In photographing spectra, when a long narrow sensitive strip is used, the plate, or the flexible film when that is used, is sometimes curved a little with considerable advantage. But for ordinary work and as a standard condition, the flat field is the most desirable and is invariably aimed at by the optician. The difficulty with this, as with most aberrations, is that the reduction of it leads to the increase of some other undesirable condi-

tions, so that finally it is a matter of compromise, and the best objective would not of necessity be the one with the flattest field, but that one which had all its residues of aberrations so well proportioned that none was excessive. In modern lenses this difficulty is much reduced, because of the greater choice of material and the constant striving of mathematicians to improve their formulæ. There are now available lenses that have so nearly a flat field, that the deviation from flatness could not be detected in ordinary photographic work. The slight residual want of flatness is often of a more complex character than the simple curve illustrated. It may for example be a double curve, and the focus at the centre of the plate may be a little nearer the lens than the focus at a short distance from the centre.

Curvilinear distortion is the condition that leads to the representation of a rectangular object, such as the front of a building, with its four boundaries bulging out like the sides of a barrel, or bulging inwards like the contour of a pincushion. Such distortion is of course inadmissible when it is sufficiently marked to catch the eye. The older photographers considered that distortion of this kind, and indeed of other kinds, did not matter in the representation of subjects of a nature that could not reveal their existence. A landscape photograph, for example, with no telegraph posts or buildings in it might suffer very severely from this form of distortion, and yet the stranger looking at the picture, even if he thoroughly understood the matter, might be unable to detect the fault for the want of some standard of comparison. The folds of a lady's dress may vary very greatly, and therefore, if in a portrait they are not exactly of the shape that they happened to be at the time, who is the wiser, and what does it matter? But this is quite a wrong attitude to assume. It might as well be argued that there is nothing wrong in deception so long as you are not found out. There is no excuse whatever at

the present time for the getting of appreciably distorted images, though it may be again emphasised that the correction of this aberration is never absolute, and therefore a lens that is quite satisfactory in an ordinary sense may be useless for surveying by photography, because here the image must be such that it will bear critical measurement without revealing any error above a certain known small maximum.

This distortion is called curvilinear, because the curving

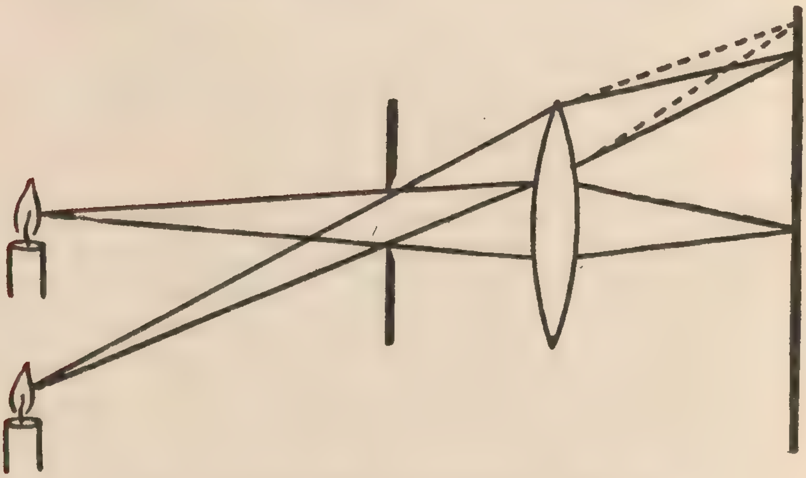
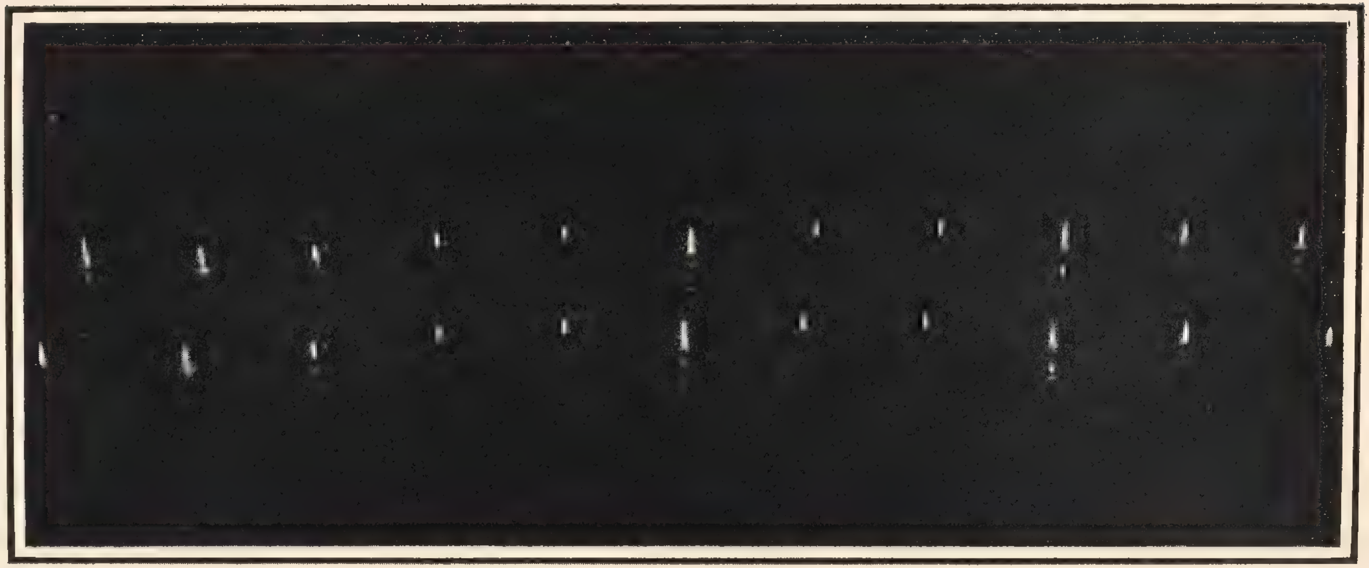


FIG. 15.—The origin of "curvilinear" distortion.

of lines that should be straight is the most striking indication of its presence, but the name does not indicate its real character at all. We have already seen that a beam of light has its path so bent in passing through a prism, that on its exit the light travels in quite a different direction from its original path. We have seen too that we may regard a lens as a combination of prisms with curved surfaces. If therefore different parts of the lens are used for getting different parts of the image, we run the risk of getting the beams of light that give these different parts bent out of their true paths. It is necessary to have a diaphragm, that is a hole of adjustable size, in connection with a lens in



C. J.

DIAPHRAGM DISTORTION

The eleven candle flames were placed at equal distances. The upper row is photographed with the diaphragm in front of the lens, and the lower row with the diaphragm behind the lens. In the first case the distances between the images gradually decrease toward the margins of the plate, while in the second case they increase

order to regulate the amount of light that is admitted to the camera, and as the diaphragm is not advantageously placed close to the lens, we have in this arrangement exactly the circumstances liable to produce the fault. Fig. 15 is a diagram of two candles, and a lens with a diaphragm that is giving images of the candles on a screen. The prism-like action of the margin of the lens bends the whole beam of light that forms the image of the lower candle so that its image is not formed as shown by the dotted lines, but is displaced towards the centre of the screen. By putting the

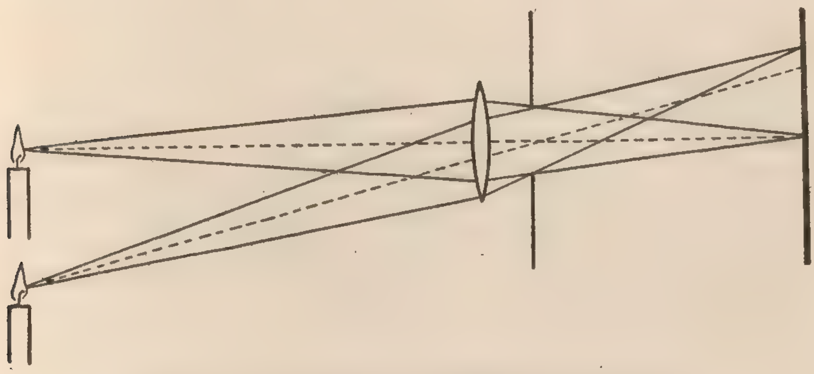


FIG. 16.—The origin of "curvilinear" distortion.

diaphragm on the other side of the lens the displacement will be in the opposite direction, as shown in Fig. 16.

Thus we get those parts of the image that do not fall just on the centre of the plate displaced outwards or expanded, or displaced towards the centre or contracted, the displacement in either case increasing in extent towards the margins of the plate. In order to illustrate this in a practical way, several lighted candles were placed in a row with exactly the same space between each and the next. A photograph was then taken with the diaphragm in front of the lens and another with the diaphragm behind it. In an undistorted photograph, as the flames are the same distance apart, the images of them should be also the same distance apart, but in these two photographs which are

shown in the illustration facing page 56 measurement will prove the fact if the eye cannot see it, that in the one case the images of the flames get nearer and nearer together, and in the other farther and farther apart as we go from the centre towards the margins of the plate.

This growing expansion in the one case and growing contraction in the other is illustrated in a rather exaggerated way in Fig. 17, by the effect that it would have upon a series of concentric circles drawn at equal distances apart. The central drawing represents the original object, the one on the left the image produced with the diaphragm in

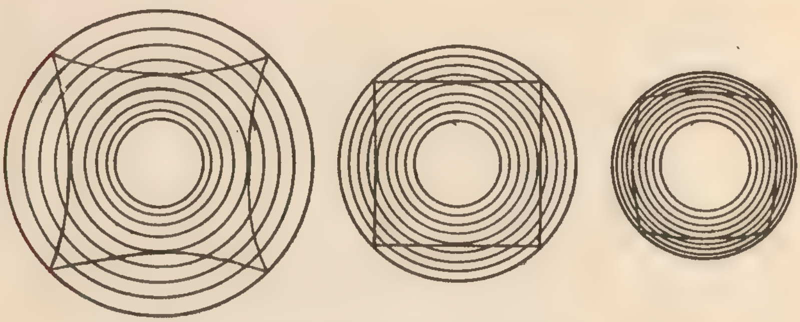


FIG. 17.—Curvilinear distortion.

front, and the one on the right with the diaphragm behind the lens. And the effect upon a square is shown at the same time. As the angles are farther from the centre of the plate than the middles of the sides, they are displaced to a greater extent, and so the line, straight in the original, is curved in the image, curved inwards or outwards as the case may be. This aberration is corrected by putting a lens on each side of the diaphragm so that the distortion produced by each may be in an opposite direction, and thus a "rectilinear" lens is produced. The lower lens in Fig. 18, and the two lenses in Fig. 19, are examples of such a construction.

The nature of spherical aberration was indicated in the last chapter. A single lens with spherical surfaces bends

the light that passes through it near its edges to an undue degree as compared with the light that passes through its central parts, so that each annular portion of the lens passing outwards from its centre produces its image nearer and nearer to the lens. This leads to a want of precision in the image wherever the screen may be placed to receive it. It may be asked, if spherical surfaces cause this difficulty why not shape them to more suitable curves? The answer is that other curves would lead to other difficulties, that they would be more troublesome to produce, and that it is possible to correct spherical aberration in compound lenses by a suitable selection of the depths of curvature of the various surfaces. There is here a wide opportunity for variation. A single lens of a fixed diameter and fixed thickness at its centre, may have the necessary curvature divided between its two surfaces, or one surface may be flat and the other more curved, or the curved side may be made of a still deeper curve and the flat side hollowed out, that is, made concave, like some spectacle lenses are now made in order to keep the glasses away from the eyelashes. Spherical aberration is controlled by the depth of curvature and by the distances between the components of compound lenses.

Astigmatism is a common fault in the human eye, and may be recognised when it exists by looking at an object or drawing like a wheel with spokes. By shutting one eye and directing the other to the centre of such an object, while some of the radiating lines will be seen clearly defined those at right angles to them will appear misty or out of focus if astigmatism is present. If the object is comparatively near to the eye it may be possible by altering its distance to get a clear vision of the lines that were misty, but those that were clear at first will now be ill-defined. This phenomenon is due to the lens of the eye inclining towards the shape of an egg flattened sideways instead of the shape of a flattened ball. The curvature is of longer

radius in one direction than in the other, and this causes the distance at which a distinct image is produced to vary according to the direction of the lines of the object. Astigmatism in the eye affects the whole of the field of vision, because it is due to the misshapen lens. But as the surfaces of photographic lenses are all of spherical curves, there cannot be any effect similar to astigmatism in the middle of the plate. On passing towards the margins, however, an effect exactly similar to that just described begins to be obvious and increases as the distance from the centre of the plate becomes greater. It is due entirely to the obliquity with which the light from the marginal parts of the object impinges upon the lens surface. Astigmatism of the eyes is corrected by the use of spectacles that have lenses with an equal amount of astigmatism but in the opposite direction. In photographic lenses it is corrected in a similar manner, that is, by taking care that some components err in one direction and some in the opposite direction, and that the opposing aberrations of the parts balance each other.

The last difficulty that we will refer to that stands in the way of getting a perfect image, is chromatic aberration, or the fault of colour. We know that the whole function of a lens is to bend rays of light that are divergent and so cause them to converge to the place where they are wanted to increase the brightness of the image. But whenever a ray of light is bent by passing it through a medium different from that in which it is travelling, the various components of which light in general consists are bent to different extents. We see this in the rainbow, for this is produced by the drops of rain through which the sun shines bending the rays out of their original course, and the effect of the bending is the colours of the bow, the blue is bent more than the green, the green more than the yellow, the yellow more than the orange, and the orange more than the red.

c. A.

THE INNER SIDE OF THE CENTRAL WEST DOOR OF BEVERLEY MINSTER

This separation of the various colours that are mixed in white light takes place to a noticeable extent with a simple uncorrected lens. If the lens was so curved that it produced the image of a distant object about twelve inches behind the lens, then the image produced by the blue or violet rays would be about the third of an inch nearer to the lens than the image produced by the red rays, and the images produced by the other colours would range in due order between. So instead of a simple image produced by the white light, we have as it were a block of images, about one-third of an inch thick. If these images were all distinct and separate the case would not be so troublesome, because we might be able to pick out just the image that we want. But the light that forms each image travels through the whole space from the lens to the screen, and therefore any one of these coloured images that we might select must be mixed up with the out-of-focus images produced by all the other colours, and this mixing is inevitable so long as white light is employed.

The aim of the optician in correcting the colour fault of lenses is to bring all this block of coloured images within a shorter distance, so that instead of being about the third of an inch thick in a lens of twelve inches focal length, it may be reduced to, say, a tenth of an inch or the fiftieth of an inch, or to as small a thickness as possible. According to the principle already given, it is never possible to reduce this space through which the coloured images are produced to nothing, so that there shall be no separation of the constituents of the light, but it is possible to reduce it to so small a dimension that it becomes negligible in ordinary work. The method of correction is similar to the treatment of other aberrations, namely, by getting a similar kind of aberration but in an opposite direction, and combining the two lenses so that they neutralise each other as far as possible. As the proportional separation of the colours is not the same in different

glasses and other substances available, they cannot be made exactly to match even theoretically. So an achromatic lens is one in which those coloured images that are formed nearest to the lens are pushed away from the lens to a greater extent than the others, in such a way that the image left the nearest to the lens may, for example, be yellow, while the green is pushed beyond it to the same plane as the red image, the blue image being still farther away. Not more than two different coloured images can be brought into exactly the same place by this method. But by the use of a third correcting element it is possible to get three of the different coloured images to exactly the same plane, and a lens in which this is accomplished is called "apochromatic." Other things being equal, it is clear that if three colours are brought together, the thickness of the colour-block, or the distance over which the coloured images are distributed, will be more reduced than when only two are made to coincide. It may thus be reduced in thickness to a fifth or even a tenth with an apochromatic of what it is with an achromatic lens.

The apochromatic correction is met with chiefly in microscope objectives, in which it is of importance to get the finest images possible, because they have to stand an enlargement up to about ten or it may be even twenty or more times linear by means of the eyepiece. An image that is a tenth of an inch long may appear to be quite satisfactory. It may remain good and sharp when magnified up to half an inch or even one inch in length. But when magnified up to two inches in length it may become diffused instead of sharp to the eye. All images produced by lenses "break down" or become ill defined or fuzzy if magnified sufficiently, and the amount of magnification that the image will stand is a measure of the correction of its aberrations.

Thus with so many corrections to make simultaneously it is not surprising that the complete lens, or objective,

is often very complex. A few types contain three lenses, a greater number contain four, more still six, some eight, and a few even more than eight lenses put together to form what we understand as the "lens." The perfection does not of necessity depend upon the number of component parts, any more than the quality of a manufactured article depends on the number of tools used in its construction, but, other things being equal, in both cases as the number increases, the opportunities for improvement increase also.

For a long time opticians had only a very few kinds of glass at their disposal. Their power to improve optical instruments was thus very restricted, but to attempt to make new kinds of glass was not a work to be lightly undertaken, for it meant long and tedious experiments to discover the direction in which the properties of the glass would be changed by the use of new constituents. However, in 1881 experiments in this direction were started by Dr. O. Schott assisted by Professor Ernst Abbe in Jena. Eventually they were assisted financially by the German Government, and the final outcome of the investigation was the establishment of the celebrated optical glass works at Jena, where a hundred or more varieties of optical glass may be obtained, and an optician who wants a glass of any other special kind may, within reasonable limits, rely upon having a quantity prepared for him. It took opticians and mathematicians many years to make effective use of these opportunities for improving objectives, and the firm of Zeiss, who were pioneers in this matter, proposed and put upon the market many forms of objectives that were afterwards withdrawn in favour of superior designs. The new glasses facilitated all the corrections, but it was especially in the reduction of chromatic aberration and astigmatism that the chief progress lay.

The early investigators and experimenters in photographic processes had no lenses specially made for the

purpose of giving a suitable image because there was no demand for such instruments, so they had to take the lenses that were to hand and make the best of them. These were such as were made for telescopes, ordinary achromatic lenses made of two lenses, a flint glass and a crown glass, cemented together with Canada balsam. These lenses were made for the purpose of giving a good image over no more than the small area that the eyepiece of the telescope allowed the observer to see. When such a lens was used for the production of an image over a comparatively large area its shortcomings were very obvious. The definition in the middle of the plate was satisfactory, but towards the edges the image rapidly faded into confusion. By turning the lens round so that the outward side became the inward side, the sharpness in the middle of the image was a little degraded, but at the edges of the plate it was somewhat improved. By mounting it in a tube and fixing a diaphragm at the outer end of the tube at a distance about equal to the diameter of the lens, the defining power was still better. The first lens shown in Fig. 18 illustrates this construction. The farther the diaphragm was removed from the lens the flatter was the field, or image—a clear advantage; but at the same time the curvilinear distortion was increased, and the area of image produced by the lens diminished. Within reasonable limits, the smaller the opening in the diaphragm the better the definition, but at the same time the longer the exposure necessary. And this reduction of the diaphragm increases the necessary exposure very rapidly, because the exposure depends upon the area of the opening that admits the light. A diaphragm of half the diameter will necessitate four times the exposure, as in reducing the diameter of the opening to one-half, its area has been reduced to one-fourth.

The long exposure made necessary by the small aperture of the lens was of very great importance when

photography first became a practical art, because the sensitive material was then so much less sensitive than it is now, and also because the chief application of photography at that time was in the direction of portraiture. It might not matter that an exposure of several minutes' duration was necessary when photographing a building or a landscape, but it was out of the question to ask people to sit or

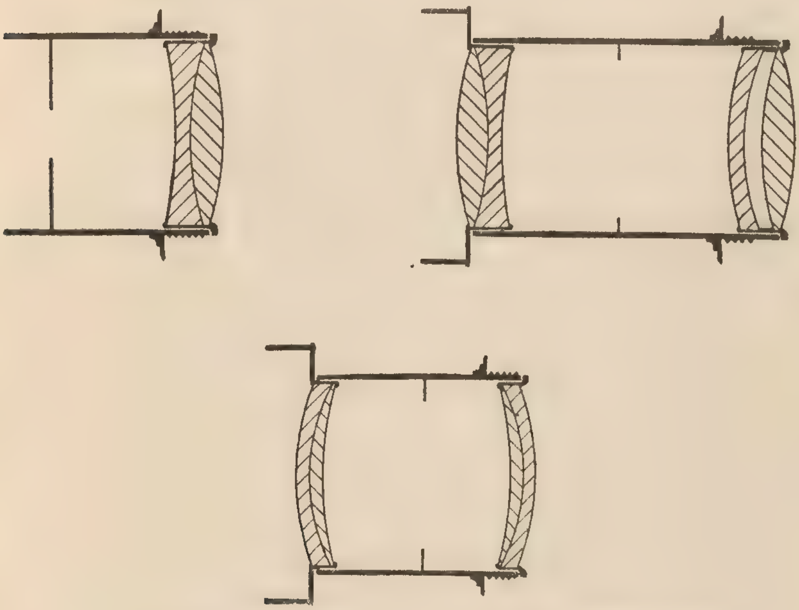


FIG. 18.—A Single Lens. Petzval's Portrait Lens. A Rapid Rectilinear Lens.

stand still for such a time, after the first novelty of the possibility of getting "sun pictures" had passed away.

The need for a lens of a larger aperture, and giving therefore a more brilliant image, was obvious to everyone, but Professor J. Petzval, a mathematician in the University of Vienna, applied himself practically to the question and calculated the portrait lens that bears his name, and that in spite of many competitors holds its own to this day. The character of this lens is shown by the second drawing in Fig. 18. The new lens was made by the firm of

Voigtländer of Vienna, and was available for general use about two years after the Daguerreotype, the first practical photographic process, was made known. Petzval used two compound lenses, one on each side of the diaphragm, and corrected the aberrations so well that exquisitely sharp definition was obtained in the middle of the plate even when the full aperture of the lens, unreduced by the diaphragm, was employed. This lens at once shortened the exposure to about one-eighth or even less of that previously necessary.

But the new lens was specially intended for portraiture, and was not very well adapted for general views in which it is desirable sometimes to include a wide expanse of country and show the detail at the margins of the plate with very nearly the same sharpness as at the middle. The older lenses therefore continued to be used for such work as this, and after a few years improvements were effected in them. Thus there were the two sorts of lenses, portrait lenses and view lenses, and these two general types remained distinct for a long time; the one slow but giving good definition over a large angle of view, and the other rapid and giving sharp definition in the centre of the plate but falling off towards the margins.

In 1866 a lens intermediate between these two types was introduced, and one that has enjoyed probably a greater popularity than any other. It has two similar compound lenses with a diaphragm between, as shown by the lower diagram in Fig. 18. Steinheil called them "aplanats," because they would work satisfactorily at full aperture; Dallmeyer called his "rapid rectilinears," because the curvilinear distortion was corrected; and Ross in 1874 called his "rapid symmetricals," because with the lens on either side of the diaphragm exactly alike, the construction was symmetrical. These were sometimes called rapid view lenses, they might equally well have been called slow portrait lenses. This kind of lens was made of very

various degrees of rapidity, and so the old distinction between the portrait and the view lens gradually passed away. There are now made lenses far more rapid than the original Petzval lens, and we may pass by almost insensible steps to lenses as slow as any old view lens. Those with the smaller apertures gain correspondingly in other directions. The applications of photography are now so numerous that they can no longer be summed up in the two words—portraits and views.

The last revolutionary progress in the improvement of ordinary photographic lenses took place about twenty years ago, and was the result of the application of the new optical glasses made at Jena. All the lenses referred to in detail above suffered to a notable extent from astigmatism and curvature of field, and these aberrations had to be reduced, when they became obtrusive, by the use of a small diaphragm, with, of course, the disadvantage of a longer exposure. Many of the new glasses were made for the purpose of facilitating the correction of these aberrations. Several lenses were designed and many actually put on the market, but the first that gained a notable degree of appreciation was the double anastigmat of Goerz, calculated by Dr. E. von Hoegh, which was introduced in 1893. (See the left hand diagram in Fig. 19.) Within a very few years almost all opticians of note had issued anastigmats as calculated by their mathematicians, varying very much in their general characteristics and construction, but all alike in being considerable improvements on the older types. One of the most highly appreciated is the "protar" of Zeiss, the right hand lens shown in Fig. 19. The chief characteristic of these modern lenses is that they give good definition at full aperture over a very much larger area of the plate, other details being the same.

Suppose that it were possible to make a lens quite free from all faults, its aberrations being absolutely

corrected, with a very large aperture and giving good definition all over a very large field, its practical use would be severely limited because of the inherent characteristics of all lenses irrespective of their aberrations. The image of each object is formed by every lens at a definite distance from it, and for the same lens this distance depends on the distance of the object. If a telescope is focussed on an object that is a long way off and then pointed to a house on the other side of the road, it must be refocussed to see clearly the details of the house, because the image of the nearer house is

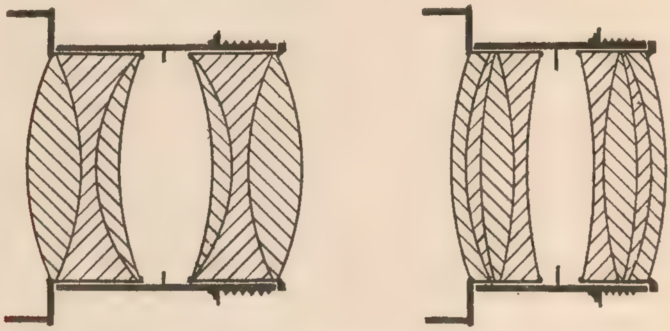


FIG. 19.—Goerz' "double Anastigmat." Zeiss' "protar."

formed farther behind the lens than the image of the object at a distance. It is exactly the same in the use of a camera. If the church or village at a considerable distance is focussed, the figure standing three or four yards away will be out of focus, and if the figure is focussed the other will be ill defined. But if both are required to form parts of the same picture they must both be got on the same plate at the same time and they must both be passably well defined. The only way to secure this is to reduce the aperture of the lens. Now as reducing the aperture reduces all the aberrations that affect defining power, it may be that with subjects that impose such limitations, one of the older lenses will give just as good a result as the finest of modern anastigmats.

On this account, and also for economic reasons, the older lenses are still extensively used. Even single uncorrected lenses, mere spectacle lenses, are sometimes employed, for if the camera and its adjuncts complete are to be sold for five shillings, the lens must be very cheap. In such a case one must be satisfied with a small diaphragm and the equivalent length of exposure, definition that is not of the finest, and other drawbacks that will be referred to later. Although anastigmats can now be obtained at a very reasonable cost, the older "rapid rectilinears" are very much cheaper, and therefore they are still used when cost is a consideration. The older lenses are none the worse because of the introduction of superior instruments. Excellent work was done with them when nothing better was to be had, and just as excellent work may be done with them still.

CHAPTER IV

THE DEVELOPMENT OF PHOTOGRAPHY

IN order to appreciate properly the position that photography occupies at the present day, it is necessary to have a general idea of the steps by which it has come to be what it is. We sometimes have such questions put to us as—Who invented photography? Who discovered photography? Who was the first photographer? The endeavour to answer these questions has led to waste of words and sometimes to loss of temper, for those engaged in the discussion have failed to settle among themselves what photography is. Is photography to date from the first attempt to produce a design by light action, the first attempt to get a permanent record, the first successful attempt, or the working out of the first method that "caught on" with the general public? Until such questions are answered we cannot say who was first. It is a matter of definition.

But if we look at the question broadly, we find that photography or light-writing is older than man himself. Before the earth was fit for him to live on the light was at work, and we can still read some of its ancient records in fossilised vegetable remains. In the oldest of historic literature there are references to coloured textile fabrics, and it is impossible to imagine that the action of light upon such materials was unobserved. It is not known how old is the practice of exposing linen on meadow land to the free action of air, moisture, and light for the purpose of bleaching it. Those employed in this work can hardly have failed to notice that a shaded portion was changed to

a much less extent than a part exposed to the full light, and this difference would constitute a light record of the fact that a part was shaded, and such a record would naturally be accepted as a guide for the treatment or care of the material. It may be objected that if this is called photography then a mere blot of ink must be called a writing. We will not argue as to whether intelligibility is a necessary attribute of all writings, nor refer to human intervention, nor consider the connection of motive with the matter, but endeavour to give a concise account of those circumstances that are immediately connected with our subject.

We have already seen, and shall see more in detail subsequently, that the camera is not of fundamental importance in photography. But as it has been and even still is often considered to include the lens, the camera and lens being regarded together as the image-producing instrument, the history of the camera is not without interest. In countries where the sunshine is much more brilliant than we in England are accustomed to, and where its very brilliancy leads to the necessity of excluding it, there must often have been noticed an image of exterior objects on the wall of a room opposite a keyhole or chink. Major-General Waterhouse states that in India he often saw vivid pictures so produced on the wall of his bungalow. This is the very essence of the camera. We only want a bigger hole to let in more light and a lens or mirror to get a sharp image and the apparatus is complete.

Roger Bacon (born 1214, died 1284) was, so far as known, the first to refer specifically to such an apparatus, though the use of image-producing lenses and mirrors was known more than a hundred years before he was born. Bacon refers only to the use of a mirror or speculum for producing the picture. The first reference to the use of a lens for this purpose appears to have been

made in 1568 by Daniello Barbaro in a book on perspective published in Venice, who directs that "an old man's glass convex on both sides, not concave, like the glasses of youths with short sight," should be fixed in a hole in the window, and all light stopped out except what comes in through the lens. A piece of paper is held at the most suitable distance from the lens, and the image, he says, will be better if the lens is partially covered so that only the central portion is used. Giovanni Baptista della Porta, who lived in the sixteenth century, has often been stated to have invented the camera, but he appears only to have popularised it and given rather more particular instructions concerning it, doubtless introducing a few minor improvements in its details. The aim of these and numerous other of the earlier users of cameras, was either the amusement of spectators, or to illustrate the rules of perspective, or else to facilitate the drawing of the object depicted. There could have been no thought of the application of the apparatus to photography, because there was not available any suitable sensitive material to receive the image on. To them the very idea of it, if it had been suggested, would have appeared as wild and impossible as the use of steam instead of horses for the purposes of locomotion, or the use of the same steam power instead of candles and lamps for the illumination of their dwellings.

At about the same time that Porta and Barbaro lived the alchemists were still at work, seeking in their enigmatical methods to find a way of turning base metals into gold and to find a method of curing all human ills. Silver chloride, called horn silver, was known to them as a mineral, and there is some evidence that they were aware that it became darkened or blackened when exposed to the light. It is difficult to believe that this was not known long before, as Geber, an Arabian who lived in the eighth century, prepared nitric acid, dissolved silver in it and

obtained silver nitrate in crystals. He added sal ammoniac (ammonium chloride) to the nitric acid and so obtained aqua regia, with which he dissolved gold and other substances, and he says that he dissolved silver also in it. When aqua regia acts on silver, silver chloride is produced. Or if, as is very likely, he added sal ammoniac to the solution of the silver in nitric acid, silver chloride would have been precipitated as a white insoluble powder. It would be improbable that experiments of this kind should have been made in daylight without noticing that the silver salt darkened in the light. But there was no reason why special notice should have been taken and recorded of this fact, any more than, for example, that silver was a white metal and copper red.

In 1727 a German physician, Dr. John Hermann Schulze, of many and various attainments, for he was in turn professor of anatomy, Greek, Arabic, eloquence and antiquities, and a historian of ancient medicine, while reading about a certain phosphorescent substance, took it into his head to try to make some. The first operation in its preparation consisted in adding nitric acid to chalk. He took some acid that he happened to have handy, probably it had been used before as it had a little silver in it, and his chalk in a dish to an open window where the sun was shining and began to pour the acid on the chalk. He was soon surprised to see that the surface of the mass changed from white to a dark violetish red where the sun shone on it, but not where the edge of the dish shaded it. He proceeded to investigate the cause of this change, using the pasty mixture in medicine bottles for the sake of convenience, and found that heat would not produce the colour. Then he cut out words or even entire sentences in paper, like stencil plates, attached these perforated papers to the bottles of mixture with wax, and exposed them to light. The words were then clearly visible on the contents of the bottles, to the wonderment of curious on-

lookers. By shaking the bottle, the darkened portions, which were only on the very surface of the sloppy or pasty mass, became mixed up with the bulk and the experiment could be repeated. He investigated the matter and found that it was the silver that caused the sensitiveness to light, and that the chalk might be replaced by magnesia, white lead, and other similar substances. He not only did not attempt to fix the photographs that he produced, but was particularly careful to keep the mixture in such a condition that it could easily be shaken up to get rid of the impression and so be ready for the next experiment.

We see in these experiments of Schulze the true spirit of careful observation and experimental inquiry, for during the previous hundred years or so the aims and mysticism of alchemy had gradually given place to what we now understand as scientific methods. It is easy to say that whatever Schulze did that had not already been done was not worth the doing, for the sensitiveness of silver salts to light had been known long before. But every little step helps the cause forward, and the emphatic demonstration of a known fact may be even more helpful than the discovery of a new fact or a new application.

Silver nitrate at this time had been known for hundreds of years both in the solid form and in solution, and it was used in surgery. It was a familiar substance among those interested in such matters, and it is not surprising therefore to find that it was recommended for use as a secret ink about the time that we are now considering. By writing with its solution on paper in a subdued light, the inscription was invisible, but on exposure to light it would gradually grow dark. Not a very practical or safe secret ink, but the proposal to use it for this purpose shows that the action of light on silver compounds was becoming more widely known and that there was a tendency to apply it to useful purposes.

Charles William Scheele, a Swede, who had been successful in isolating chlorine from hydrochloric acid three years before, in 1777 investigated the change that light effects in chloride of silver. Whether or not the alchemists knew that silver chloride became darkened by exposure to sunlight, it was before this a well ascertained and recorded fact, and Scheele, who was an indefatigable investigator, was interested in the action of light in general and especially in its relation to the action of heat upon substances. He prepared a quantity of silver chloride, dried it, and exposed it to sunshine for two weeks, stirred it up and exposed it again, and so continued until he obtained a practically black powder. This he treated with ammonia, which dissolves silver chloride, and obtained a black insoluble residue which he identified as silver. Hence he concluded that the action of light consisted in the separation of metallic silver from the chloride of silver. In another experiment he exposed to the light some chloride of silver in water, and he found that the water contained the chlorine that the light had separated from the silver salt. The inferences drawn from these observations we know now to need a little modification, but in the main they are correct. Scheele went even further than this, for he coated some paper with chloride of silver and found that violet light acted upon it to darken it more quickly than any other rays of the sun's spectrum.

Experiments of the kind just described were made by other investigators, some of whom carried their researches further than their predecessors, but we are not particularly concerned with them. Our present aim is to get an idea as to how matters stood at the end of the eighteenth century, that we may better understand the attitude of those whose work is now to be referred to. The sensitiveness of various silver compounds to light was then well known, silver salts had been spread upon paper for the purposes of investigation, and the character of the change produced by light had

been discovered by an examination of the products in the case of silver chloride as well as the nature of the active light.

We may not think much of a suggestion made by Lord Brougham in 1795 when he was a youth of seventeen, to rub silver nitrate on ivory and on the surface to receive and so render "permanent" the picture produced by the camera. This suggestion was deleted from a communication that Brougham sent to the Royal Society, and he does not appear to have considered that it was worth taking further trouble about.

Thomas Wedgwood, the fourth son of Josiah Wedgwood the renowned potter, was born in 1771 and suffered all his short life (he died at thirty-four years of age) from ill-health which gradually unfitted him for any work except travelling in the endeavour to mitigate his sufferings. He had a distinct taste for scientific pursuits, and was interested especially in the effects produced by light and heat. He worked with a solar microscope, that is an apparatus that utilises the direct rays of the sun to give on a screen an enlarged image of suitable small objects, and he became anxious to make "permanent" the images so produced. The word permanent here does not mean that the picture should of necessity last for long, but only that the picture should be so "fixed" on the screen that it should remain after the apparatus producing it was removed. For this purpose he used silver salts, especially the nitrate, and probably worked on and off as circumstances permitted for some years in his endeavours to get satisfactory results.

Sir Humphry Davy began to study chemistry in 1798, in the following year he began an important series of experiments on the inhalation of nitrous oxide, and in 1801 he left an appointment that he held at Bristol to come to the newly established Royal Institution in London. When Davy came to London he was a young man twenty-three years of age and Wedgwood was twenty-nine. Wedgwood showed Davy his results either in this or the

A Sunset Sky

following year, perhaps seeking the advice of the young chemist with regard to some means for preventing the light from obliterating his photographs by blackening all over the paper on which he had produced them. All that is really known is that in 1802 there was published in the Journal of the Royal Institution a communication with the title "On an account of a method of copying paintings upon glass, and of making profiles, by the agency of light upon nitrate of silver. Invented by T. Wedgwood, Esqr. With observations by H. Davy." Paper or leather was moistened with a solution of nitrate of silver and the image allowed to fall upon it. The colour of the impression produced could not be washed out with soap and water, but all attempts by repeated washing or varnishing to render the uncoloured portion of the paper indifferent to light, to "fix" the print as we should now say, were unsuccessful. The hyposulphites, the ordinary fixing salt of to-day, had been discovered three years before, but it was only a laboratory curiosity and perhaps it had not come under Davy's observation. Leaves, insects' wings, and ordinary printing press prints could be copied slowly by putting the sensitive paper in contact with the original and exposing to light, but a camera image was too faint to produce a result. Davy says that to secure the camera image was the first object of Mr. Wedgwood, but that in this all his numerous experiments were unsuccessful. Davy tried silver chloride and found it more sensitive than the nitrate. He refers to some possible future experiments with regard to "destroying" the sensitive compound not acted on by light (fixing), and adds that this is all that is needed "to render the process as useful as it is elegant." These further experiments do not seem to have been made. Three years after this Wedgwood died, and Davy, who was busy with the duties of his position and his chemical investigations, probably gave no further thought to the matter. In 1829 Davy died.

The next two men that we have to refer to, worked at the perfection or discovery of a photographic process with an unprecedented perseverance. They are the first men who really devoted themselves to the matter. Joseph Nicéphore Niépce was born at Châlons-sur-Saône in 1765, six years before Thomas Wedgwood was born, educated for the Church, but at the time of the French revolution became a soldier. After this he settled down at his birthplace and indulged his scientific tastes. In 1815, or about then, he began his photographic experiments with the idea of finding if possible a method of automatically copying designs upon lithographic stones, so as to save the tedious work of the draughtsman. Lithography was a comparatively new art at that time, and was just beginning to be appreciated in France. From the stone, he passed eventually to tin, pewter, silver, and even glass. The sensitive substance that he was most successful with was bitumen or asphalte, which he dissolved to form a varnish and then applied so as to obtain a film on the surface to be treated. This film of varnish when exposed to light would show no sign of change, but where the light acted it would become less soluble, so that on applying a weak solvent, such as a mixture of oil of lavender and petroleum oil, the parts that were not changed by the action of the light would dissolve more readily than the other parts, and with due care a good picture would be obtained, the varnish left on the plate corresponding to the light or white parts of the subject. Niépce succeeded in getting pictures in the camera with six or eight hours' exposure, and he could copy a transparent print laid direct upon the plate and exposed to light in about two hours. Some of these pictures on metal he put into acid that dissolved or etched the metal where it was not protected by the varnish, and from these he got prints by the ordinary method of the printing press. The pictures produced on silver showed the reddish varnish in the parts corre-

sponding to the bright parts of the object, and the white metal corresponding to the dark parts or shadows. He tried to darken the metal where it was exposed to make the appearance more natural, and the substance that he was the most successful with for this purpose was iodine, which does darken silver very effectually. The varnish could then be dissolved away, and now the white silver would represent the lights and the darkened silver the dark parts of the object or print.

Thus Niépce was eminently successful from an experimental point of view, for he not only got his pictures, even those produced in the camera, but he succeeded in fixing them, using the word "fix" in its present-day sense, and those of his pictures that have been taken care of show little or no deterioration. Moreover he produced invisible images which he developed.

Louis Jacques Mandé Daguerre was twenty-two years the junior of Niépce and a very different sort of man. He was born near Paris, and was perhaps the most celebrated scene-painter who has ever lived. He was not only successful as a man of business, but he was ingenious and original in his methods. He used a camera obscura to help him in his painting, and about the year 1824 was moved with a desire to try to "fix" the camera image. We do not know what gave rise to this desire, whether he hoped that it would help him in his drawing, or whether, as seems more likely, he thought that if successful the production of pictures in this way would excite the interest of the public and be profitable to him. He seems to have been working with phosphorescent substances, that is substances which when illuminated continue to shine after the light that illuminates them is withdrawn. Perhaps he hoped to get self-luminous pictures in this way, for we know that he was original and successful in the manner in which he illuminated his dioramas. Charles Chevalier, who was a maker of optical instruments

and had a shop in Paris, used to supply Daguerre with apparatus, and he knew the direction in which he was working. In 1826, either Niépce or his father went to Chevalier's to see about getting a camera, and in this way Chevalier came to know of Niépce's success. He told Daguerre of this, and Daguerre immediately wrote to Niépce on the subject. Niépce was reticent and cautious, but Daguerre was genial and persevering, and the result was that in 1829 the two men entered formally into partnership. According to the agreement, Niépce told Daguerre how he had succeeded, and in return Daguerre contributed some detail with regard to an improvement in his camera. Daguerre, the pushful and younger man, seems to have had the best of the bargain, but Niépce had been disappointed that his results, which he brought also to this country, awakened practically no interest, even among scientific men. Niépce was now sixty-four years old, and four years after this he died.

Niépce used iodine to blacken the silver plate, as already stated, after he had got his photograph, and it was doubtless this that led Daguerre to work with silver darkened on its surface by iodine fumes. But Daguerre used this darkened silver surface as the sensitive surface, which Niépce appears never to have done. By 1837, Daguerre had by sheer perseverance, so great that his wife had doubts as to his sanity, brought the Daguerreotype process to a practical form. He and Niépce's son, Isidore, endeavoured to put the process on a commercial footing, but the incredulity and indifference of others they could not overcome. Probably as a last resource Daguerre went to Arago, the most celebrated scientific man in France, and he saw enough of the possibilities of the process to become enthusiastically interested in it. Through Arago's influence Daguerre and the younger Niépce were given substantial pensions by the French Government on condition that they published the details

of the process, and this was done in 1839. The process consisted in exposing the polished surface of a silvered copper plate to the fumes of iodine until it was coated with a compound of silver and iodine. The plate was exposed in the camera, and then developed by putting it over a dish of gently warmed mercury. The mercury vapour deposited on those parts where the light had acted, but not on the other parts. Where the light had acted to a small extent, there was a correspondingly small deposition of mercury, so that the lights and shades were well reproduced. The silver iodide was then dissolved away by hyposulphite of soda, just as negatives and silver prints are fixed at the present day.

Daguerreotype was the first method of photography available for practical purposes. As soon as the necessary details could be obtained a great many persons took up the process. The plates were eventually made more sensitive by the use of bromine in addition to the iodine, and other improvements were effected; and Petzval devised his portrait lens, which still further reduced the very long exposures at first necessary. Daguerreotypists gradually increased in number in practically all parts of the civilised world, and photography became a "profession." So far as the general public were concerned the process had no rival until after 1851, the year in which Daguerre died and the collodion process first saw the light. A few years after this the Daguerreotype process became practically obsolete.

The announcement of Daguerre's success in 1839, coming with the stamp of the authority of the French Government, at once attracted attention. Indeed before it was announced some preliminary information was circulated, and this urged into increased activity others who were seeking to make photography practical. W. H. Fox Talbot, who had been working on similar lines to Wedgwood and Davy, sent two communications to the Royal

Society early in 1839 showing that he had obtained a much greater sensitiveness than the earlier workers and had succeeded in "fixing" the result. He used silver chloride for his sensitive substance, impregnated paper with it for use, and fixed either with a weak solution of potassium iodide or a strong solution of common salt. Three weeks after this Sir John Herschel, who had heard seven weeks before that Daguerre had a successful process ready to be made public, accepted the statement "as an enigma to be solved," and finding silver chloride on paper lacking in sensitiveness used nitrate of silver. For removing the unaltered silver compound after the exposure in order to fix the photograph, he used a hyposulphite, which he had previously recommended for this purpose. He made not only what we now call negatives, but also "second transfers," as he called them, or what we now understand as prints or positives. He showed twenty-three photographs, "one, a sketch of his telescope at Slough, fixed from its image in a lens; and the rest copies of engravings and drawings." There was one other worker of note who brought forward his results at this time, namely the Rev. J. B. Reade, a scientific man of a retiring disposition, who appears to have been the only one that really sought to follow up the experiments of Wedgwood. Early in 1837 he was anxious to save the cost of an artist for drawing the magnified pictures that he projected on a screen by means of his microscope, using either sunshine or the oxyhydrogen light, and so endeavoured to get photographic impressions. As Wedgwood and Davy had found that leather gave a more sensitive surface than paper when impregnated with the silver salt, he used light coloured leather gloves until the supply failed. Then he said "I will tan paper." For this purpose he applied an infusion of galls to the paper in addition to the silver salt, and so obtained a greatly enhanced sensitiveness. He obtained a photograph of a

flea by means of his microscope in less than five minutes, and sections of wood were photographed with an exposure of from eight to ten minutes. The sensitive paper so prepared could be used in the camera. Reade used sodium hyposulphite for dissolving away the unaltered silver salt.

Two years later, Fox Talbot effected a very great advance in the sensitiveness of his paper, making it more than a hundred times as sensitive as any known before, he says. He had accidentally discovered that it was possible to produce with silver compounds a latent or invisible impression that could afterwards be developed. Both Daguerre and Niépce developed their photographs from invisible images, but this kind of development appears to be radically different, as we shall see in detail when we come to consider the subject. In this process of Fox Talbot's, which was called "calotype," paper was impregnated with silver iodide, and shortly before use washed over with a mixed solution of silver nitrate and gallic acid. After exposure in the camera no change was visible, but after removal, if the paper was washed over with more of the gallic acid and silver solution and gently warmed before the fire, the image gradually appeared and grew to an intense blackness. With an ordinary slow view lens one minute's exposure would suffice for a building in sunshine, and with a rapid portrait lens a white bust in sunshine needed only one second to produce an impression that would satisfactorily develope. From these negatives Fox Talbot made prints in much the same way as they are made at the present time.

So far it will be observed that the sensitive silver compounds used were either on a metal plate or on and more or less in the substance of a sheet of paper. In 1848, Niépce de Saint Victor, nephew of the first Niépce, used a film of albumen supported on glass to hold the sensitive compound, that is a transparent film. In 1851

Frederick Scott Archer published a process in which collodion was used instead of albumen. But this is a process that still survives, and therefore must receive more detailed attention later on.

We have thus traced photography with silver salts from its earliest beginning so far as concerns the most important stages in its development. The later history will appropriately be referred to, so far as we are able, in connection with the subjects to which the details specifically refer. But if all the historical facts mentioned in this volume were brought together, they would not constitute anything like a complete history of the subject. There were other workers besides those mentioned, before 1839, and since then there have been very many indeed. They have been of all kinds, from the most learned scientific men to those who knew nothing of scientific method and hardly more of what we understand as scientific facts. They have been from the wealthiest to the poorest. Some have worked for practical results only, some for personal profit, and some rather to elucidate a theory or to discover the exact nature of the changes that take place. Photography is so varied in its methods and its applications that it may be regarded from many points of view.

There is only one other word appropriate to this chapter. The general reader may find some descriptions of processes not very clear to him. To have burdened the historical details with explanations of the changes referred to would have led to confusion, but we hope that any such difficulties will be found to be removed in the subsequent chapters.

CHAPTER V

PHOTOGRAPHY BEFORE GELATINE

In following the development of photography from its beginnings it is clear that the compounds of silver have always occupied a very important position. But innumerable substances are changed by the action of light, and if silver and its compounds had never existed photography would still be not only possible but practicable. No two substances that we can distinguish from each other are alike, for if they were they would be only different portions of the same substance, nor are the changes that they undergo exactly the same. When therefore we have a large number to select from, the problem is to choose those that offer the most substantial advantages.

The changes that light produces in silver compounds certainly were and probably still continue to be the most obvious of all such changes. Under suitable conditions silver chloride darkens almost to blackness by an exposure to daylight that is not very prolonged. This fact created a prejudice in favour of silver compounds, and it was this that led to the discovery by Fox Talbot that a short exposure to light, so short as to give no visible result, produced an instability in the parts exposed that enabled a suitable substance to produce the blackness, by its application after the light had been withdrawn. And it is in this that the particular value of silver compounds consists.

What concerns us especially now is that by this course of events the brighter the object is, the denser is the

deposit produced by its action on the sensitive surface in the camera, and if this deposit is dark, the bright parts of the object are represented by dark deposits in the image. The bright sky is represented by blackness on the plate, and the dark foliage leads to the production of very little deposit, so that we get a total reversal of light and shade. That brightness should produce darkness seemed to tickle the fancy of Schulze, who started out, as Daguerre appears to have done, by the endeavour to make or use a preparation that would shine more brightly in proportion to the brightness of the light that fell upon it, as we now say would phosphoresce. This that seemed to be a grave disadvantage to some of the earlier workers, has proved to be of the greatest service, because if this reversal of light and shade can be obtained once it can be obtained a second time. If the first photograph is used as a shield to a piece of sensitive material placed close against it while the two are exposed to light, the black sky protects the sensitive surface beneath it and then there is little or no action, while the thin deposit in the shadows allows the light to pass more freely and produce the darkness that corresponds with the original object. Sir John Herschel called the first photograph a "reverse transfer" or "first transfer," and the second "a second transfer or re-reversed picture." Shortly afterwards, "to avoid circumlocution," he called the first a "negative" and the second a "positive," and although these words do not etymologically convey the meaning attached to them, they have served their purpose in photographic nomenclature for seventy years, and doubtless will continue to do so. The great advantage of this method of work is that a negative will give any number of positives or "prints" without any further recourse to the original object.

But this method of work has another advantage, in addition to the facility that it offers for multiplying the

photographs, that is not often appreciated. Any photograph that is obtained directly in the camera as a Daguerreotype is, is "reversed" in quite a different sense from the reversal just referred to. It is optically or laterally reversed. You have only to look at yourself in a looking-glass to see an example of lateral inversion. If you raise your right hand, the image that you see in the glass raises his hand that is on the same side, but as the image faces you it is his left hand. Thus we have a lateral or sideways inversion, and all photographs taken direct suffer in this way. A negative is laterally reversed, but the positive or print made from it, as the two are face to face in making the print, is reversed again and so corrected. A negative looked at through from the back shows the image without lateral inversion.

Anyone who is not familiar with this phenomenon of lateral inversion may find another illustration help to make its character more clear. Take a piece of tracing paper, or the equivalent, and draw on it in ink some design with different sides to it, such as the profile of a person's face or the letter F. Looking at the side of the paper that you have written on the writing is not reversed, but by turning the paper over and looking at it from the back the design is laterally reversed, the face or the horizontal strokes of the letter point in the opposite direction. Now hold up the paper with its under side to a looking-glass and look at the back of the paper as seen reflected in the glass, and the reversed image will be found to be re-reversed by the reflection and so to appear in its correct position.

This lateral inversion would of course be intolerable in a portrait, as it would represent the person as if he were left-handed, any mark on one side of his face would appear on the other side, his coat would button over the wrong way, his watch and his handkerchief would be in pockets on his right hand side, his hair would be parted on

the right instead of the left, and everything would be wrong. This difficulty used to be overcome in making Daguerreotypes by putting a mirror in front of the lens and at an angle with it, and photographing the reflected image instead of the person direct. A reflecting prism was sometimes used, but the principle remains exactly the same. Mirrors and prisms are in constant use at the present day in order to correct lateral inversion in those processes that otherwise would cause the final pictures to suffer from it.

Reverting to the method of making negatives for the purpose of getting prints from them, we find that the use of paper as a support for the sensitive silver compound had many disadvantages. The water-mark, if present, and other variations in its thickness, the impurities and foreign matters that might be present, the possible variations in the sizing of it (that is the addition of substances to render it less absorbent as blotting-paper is), all tended to introduce irregularities. Again, paper is not very transparent and even if impregnated with waxy substances, as was often done, it still left much to be desired in this particular. Glass had been used by Niépce, though not apparently for the sake of getting what we understand as a negative. Sir John Herschel in 1840 used glass, and got his silver salt upon it by putting it at the bottom of a vessel that contained the silver salt suspended in water, and allowing the silver salt to settle down upon it. By carefully removing the plate and drying it, the silver salt adhered sufficiently to permit of the necessary operations, if due care was taken. He found that it was possible to get prints from photographs produced on such plates, though he did not make them especially for use as negatives, but the inconvenience and risk in both the preparation and use of them would preclude them from being generally employed.

Others endeavoured to use glass plates instead of paper,

C. J.

An Old Doorway of Marston Trussell Church

Uncovered a few years ago.

but it was not until the nephew of Niépce, Niépce de Saint Victor, in 1848, worked out a method of using a film of albumen to hold the sensitive compound on to the glass, that the production of negatives on glass became a practically useful method. Other substances were tried as well as albumen, but without much success until Frederick Scott Archer published in 1851 a method that he had elaborated of using collodion for this purpose. The collodion process is still in use for certain purposes so that it demands a more detailed consideration.

Photography as a practical art dates from the introduction of the Daguerreotype and the paper processes of Fox Talbot in 1839. There have been only two other epochs of first importance, namely the collodion process in 1851 and the gelatine process about twenty years after. The introduction of these newer processes did not mean a sudden revolution in photography as an art, for an innovation was always regarded with a measure of scepticism. It was necessary to convince those who were actively engaged in the pursuit of the advantages of the new process, then the workers had by practice to become skilled in the working of it and their apparatus had to be adapted to it. So we find that Daguerreotypes were made commercially for five or six years after collodion was used, but the facilities and economy of the collodion process finally drove the Daguerreotype process into the obsolete methods of the past. For about five-and-twenty years collodion held its own without a rival. It was collodion that popularised photography, for a Daguerreotype was a single and costly picture, while by the use of collodion those who enjoyed but slender incomes could afford to have their photographs taken now and then, and if they wished they could have copies for distribution.

There were two collodion processes, the negative and the positive, the latter giving a single picture which was always put into a frame of some sort after the style of a

Daguerreotype. In the negative process, the photographer made a negative, and from it printed the desired number of copies on paper which were finally mounted on cards. It is, practically speaking, the same process, whether it is wished to make a negative or a positive, and only the details are varied according to the end in view.

Collodion is a solution of a kind of gun-cotton in a mixture of alcohol and ether, and when the solution is poured upon any surface the solvents evaporate and leave a continuous film or varnish of the gun-cotton. Cotton when pure is a definite substance called cellulose, and cotton wool and good white blotting-paper, such as is used for filtering purposes in chemical laboratories, are nearly pure cellulose. When cellulose is put into a mixture of nitric and sulphuric acids, nitrates of cellulose are produced. If the action is pushed on as far as possible a nitrate is produced which if dried and set on fire burns with a sudden burst of flame. This is the gun-cotton that is used in warfare and for blasting in mines and quarries. If the action of the acids is moderated by adding a little water or shortening the time that the cotton is subjected to their action, a less explosive compound is produced which is called "soluble gun-cotton" or "pyroxyline," and it is this substance that is dissolved in a mixture of alcohol and ether to prepare collodion. There is no possibility of accident from the combustibility of the basis of collodion when employed in the usual manner, for however combustible a material may be, it cannot be set fire to when it is spread as a thin varnish-like film upon glass or any similar support. The old experiment of wrapping a piece of paper tightly round a poker and then holding it in a flame, shows that close contact with a considerable mass of material keeps a layer of combustible material cool even when a source of heat is applied to it.

Although the collodion film plays the same part as the paper did in the older process in being the vehicle that is

impregnated with the sensitive compound, it is not convenient to prepare the film first and then treat it as the paper was treated. The sensitive compound, silver iodide in this case, is obtained by bringing together two substances that produce it by their action upon each other, and it is convenient to put one of these into the liquid collodion before the glass is coated with it. As the change produced by light during the exposure in the camera is exceedingly minute and invisible, serving only to render the silver compound amenable to the developer, great care has to be taken that the silver iodide is produced and kept in the dark, so that no light reaches it at any time whatever until it receives in the camera the image of the object to be photographed.

The collodion before use, therefore, has added to it a solution of an iodide that is soluble in the collodion solvents, generally iodide of potassium, of ammonium, or of cadmium. It is then ready for application to the glass plate. This must be scrupulously clean, for any ordinary dirty matter would be very likely to interfere with the action of the developer, either facilitating it and so causing a deposit on development where it should not be, or hindering it and so leading to the production of parts that are unduly transparent. For a similar reason the collodion cannot be applied with a brush as is often customary with varnishes, for it would be impossible to keep the brush clean. The use of a brush too would result in an uneven layer, and this clearly would be detrimental. The prepared collodion is therefore poured on to the glass plate while this is held in a horizontal position, and by a dexterous sloping of the plate the liquid is caused to flow all over it and the excess is allowed to drain off at one corner. A small plate is held in the hand, while a plate that is too large and heavy for manipulation in this way, and a piece of plate glass two or three feet square is of a considerable weight, is allowed to rest near its centre

on a well padded and suitably supported round cushion two or three inches in diameter. On such a contrivance the workman can manipulate large and heavy plates with ease.

When the film of collodion has set, but before it has dried, the plate is placed in a solution of nitrate of silver, and it is from this stage that the plate must be kept in the dark or in a room to which only such light is admitted as is unable to act upon it. The nitrate of silver is soluble in water and so also is the iodide that was added to the collodion, but as soon as these two substances come together in a liquid, iodide of silver is formed and deposited as a fine yellow powder, because it is not soluble in water. It will be seen that as the iodide added to the collodion mixed thoroughly with it, it must thoroughly permeate the film on the plate, and as the silver nitrate solution soaks into the film the iodide of silver is produced throughout its substance—the silver compound is in the film not on it. After three or four minutes the plate is withdrawn from the nitrate of silver solution (called the "silver bath"), allowed to drain a little, and at once put into its carrier and exposed in the camera.

It will be observed that the plate is wet with the solution of nitrate of silver when it is being exposed, and indeed the plate is wet all the time until it is ready for the final operations of drying and varnishing. Hence this is often called the "wet plate process." It is essential for the proper action of light that the plate have nitrate of silver upon it, and if it were allowed to dry this salt would crystallise, and the crystals being deposited here and there irregularly would cause an uneven action. The wetness is therefore a matter of necessity and not of convenience. After the exposure the plate is taken to the dark room, removed from its carrier, and a suitable quantity of the developer is poured upon its surface so

that it mixes with the silver nitrate solution with which it is already wet. The developer may be either pyrogallic acid or ferrous sulphate, but in either case its action would be too vigorous alone and therefore it is made slower and more under control by adding a few drops of acetic acid to it. If the developer does not flow evenly on the plate a little alcohol may be added to it to facilitate its flow.

Very soon after the developer has been poured on to the plate the image begins to appear, and the operator carefully watches the growing image as he causes the liquid on the plate to move a little to and fro. When the darkening of the image begins to lag, the exhausted solution is rinsed off the plate, and a mixture of some more developer with its acid plus a little nitrate of silver solution is poured on.

The darkening of the image now goes on again, and when the operator considers that it is dark enough, the plate is rinsed, put into the fixing bath to dissolve out from the film all the silver salt, for it is no longer wanted, washed, dried, and varnished. It is then ready to be used for the making of prints.

The iodide of silver in this case is the sensitive substance. The amount of light that gains access to it while the plate is in the camera produces no visible change, but it is certain that the light does produce some change, because by the after treatment those parts that the light has impinged upon behave in a different manner from those parts that have not been subjected to its action. The nature of the changes taking place during development is not difficult to understand. If the developer proper, the pyrogallic acid or the ferrous sulphate, were added to a solution of nitrate of silver, metallic silver would at once be separated from the liquid as a fine dark powder, and in time this would settle to the bottom of the vessel. By the addition of a drop or two of

acid to the mixture, the separation of the metal would be made more slow and it might be a minute or two before any change began to be visible. This is the condition of the liquid that is on the surface of the exposed plate during development. It is just ready to deposit metallic silver, but it is held back by the acid. But the acid holds it back to only a very slight extent, so that the smallest amount of disturbance from any outside source is very likely to upset the unstable equilibrium of the solution and cause metallic silver to separate from it. We have seen that light is a force and often causes changes, and it has in this case disturbed the silver iodide in the collodion film on the plate where it has fallen upon it, and this disturbed condition of the silver compound is just able to cause the deposition of silver from the solution. So silver is deposited where the light has acted, but not in the other parts of the film. After a little time the metal begins to be deposited from the developer without the action of any outside disturbing force, and the separating metal imparts a brownish tinge to the solution. If this were allowed to continue silver would be precipitated all over the plate and the negative would be "fogged." To avoid this catastrophe, as soon as the developing liquid is seen to be beginning to be coloured it is thrown off and a new solution is applied.

What is the nature of the disturbance that the light has effected in the iodide of silver? This is not known. Various theories have been suggested and the greater number or all of them have in turn been cast aside. We shall say something on this subject when we discuss exposure and development more in detail.

We have just described the production of a negative on a wet collodion plate, and seen that in the end there

is a dark deposit wherever the light has acted on the plate. If this deposit can be got white instead of grey or black, we shall get at once on the plate what may be imagined to be a white pigment corresponding in place and in quantity to the whiteness or brightness of the object photographed, and if a black material is put all over behind the plate, we have much the same result as would be obtained by an artist who started with a black surface and painted on it in white pigment a picture of the object before him. Only, of course, our photograph would be far more perfect than the artist's picture and it would lack the personality of the latter which is often so welcome and so valuable. This is a collodion positive. To get the deposit white, some ferrous nitrate and nitric acid are used in the developer instead of only ferrous sulphate and acetic acid, and it is desirable to give a shorter exposure, so that the deposit may not be so dense as to give a flat monotonous appearance even in the highest lights. The black backing may be of black velvet or a black varnish painted on. If the backing is put on the film side of the plate so that the photograph is looked at through the glass, the picture is seen correctly; but if the backing is put on the glass side so that the film is towards the spectator, the image is laterally reversed, as a Daguerreotype is when taken without the use of a mirror or reflecting prism.

A collodion positive if well made is a very beautiful production, and some have said that it may surpass the finest Daguerreotype. This of course is largely a matter of skill in the worker, but there is one circumstance that is in their favour as compared with Daguerreotypes, namely, that they have not that troublesome brightness of the polished metal that renders it necessary to turn a Daguerreotype about until the reflection is got rid of before it can

be properly seen. The collodion positive is the kind of photograph supplied by the peripatetic photographer who gives you a completed and framed picture while you wait. The whole process can be done in two or three minutes, for the thin film of collodion may be rapidly washed and if necessary dried by warming the plate, without fear of damage. A "ferrotype" or "tintype" is a collodion positive made on a piece of thin enamelled iron which itself constitutes the black backing necessary. In this case, of course, the photograph must be laterally reversed unless a mirror is used.

The necessity for having the plate wet and wet with a solution of nitrate of silver, when working the collodion wet plate process, has been pointed out. The disadvantages of this necessity are numerous and can hardly be appreciated by one who has not himself performed the necessary operations. Consider a photographer working at home in his own studio and about to take a portrait. After arranging the sitter and getting everything connected with the subject ready, the photographer must retire to the dark room to prepare the plate. When it has been in the nitrate of silver solution long enough it has to be transferred while wet and dripping, for it must not be drained too long, to the back portion of the camera, that is made removable for the purpose of conveying the plate in darkness from the dark room to the camera in the studio. It is hardly possible to prevent the silver solution from getting on to the fingers and on to some parts of the camera. It very speedily blackens the fingers and in time it rots the woodwork. In development there is more silver solution liable to get on to the hands, so that even the most careful and dexterous worker could hardly avoid justifying the description of photography as the "black art." But if a photograph had to be taken away from

home there were other and greater disadvantages. The plates had to be prepared and developed on the spot, and unless they were exceedingly small this necessitated the carrying of large bulks of solutions and also a "tent" to work in, a tent of special construction to exclude the light. The tent might be only large enough to put the worker's head and hands in, instead of his whole body, but still it had to be of considerable size to permit of the various manipulations necessarily done in the dark. The most modest outfit for outdoor work would therefore generally be an arrangement on wheels and require the aid of at least one assistant.

A "dry plate," that is a plate that could be prepared at home, and that would keep in good condition long enough for it to be taken where desired for exposure and then brought home for development, was clearly a great desideratum. The wet collodion plate could not be dried, for then the nitrate of silver would crystallise on its surface and render it useless, and the silver salt could not be washed away to permit of its drying, for that would render the plate very much less sensitive. The search therefore was for some substance that would effectively replace the nitrate of silver on the plate, not crystallise when it was dried, and at the same time form a protective film. Many substances were found to serve this purpose to a greater or less extent, and the want of a discriminating knowledge as to their constituents led various persons from time to time to succeed with and to recommend such things as tea, coffee, wine, stout, porter, gin and water, ale, jelly, raspberry syrup, raisins, eggs, rice, tapioca, honey, sugar candy, gallic acid, tannin, gelatine, &c.

These collodion dry plates were prepared as described for a wet plate, but allowed to remain rather longer in the silver bath to ensure a complete action, then instead of at

once exposing them, the plates were washed, coated with the preservative and dried. The photographer would, as a rule, prepare as many as he wanted the day before they were to be used. Such plates were generally less sensitive than a wet plate and might require as much as thirty times as long an exposure.

It will be observed that in the earliest silver methods, Wedgwood's and Fox Talbot's, the paper that was to carry the silver compound was impregnated alternately with the two substances that would produce the desired silver salt. When albumen or collodion was used the photographer himself prepared the film at the time required, and he added one of the two necessary compounds, the iodide of potassium, for example, to the bulk of the material of which he prepared the film. After the glass was coated and the film produced, it only remained to immerse the film in the other solution, that is, the nitrate of silver, to produce the required silver compound. It seems a most obvious step further, to add the nitrate of silver solution to the film-producing substance while it is still in bulk, so that the sensitive silver salt may be produced in the bulk of the material instead of in each plate separately. This clearly means a saving of labour, and a simplification of work at the time when the photograph has to be taken, for as soon as the material was poured on to the glass and the film produced, the sensitive compound would be there without further manipulation, and the need for the silver bath with all its attendant difficulties and unpleasantnesses would be done away with. There were several attempts to bring about this simplification, but it seems that the first practically successful formula was published by B. J. Sayce and W. B. Bolton in 1864, and shortly after improved and modified in many ways by these and other workers.

A liquid prepared as stated, which contains in it the sensitive compound and also the material that is to form the film, is called an "emulsion," in such a case a "photographic emulsion," because the word emulsion is of general applicability and merely indicates a milky liquid. In milk it is the little globules of butter-fat that render the liquid non-transparent or "milky," while in a photographic emulsion it is the little particles of silver salt that cause a similar appearance.

Messrs. Sayce and Bolton found that bromide of silver was better than the iodide, and this was one of the chief elements in their success. The coated plates were washed and the preservative applied as if they had been prepared by the use of a silver bath. Some ten years afterwards the washing was done by Mr. Bolton on the bulk of emulsion instead of each single plate being separately washed. This was another considerable advance, for every operation that can be carried out on the bulk of material instead of upon the individual plate, means not only a saving of time and an economy of material, but a greater uniformity in the properties of the several plates prepared from the batch of emulsion. The washing is effected by adding water a little at a time to the emulsion, which it will be remembered is a solution of pyroxyline (gun-cotton) in a mixture of alcohol and ether containing also the sensitive silver salt, and as the pyroxyline is not soluble in water it is gradually thrown out of solution in a curdy form, but still retains the silver salt. Or the alcohol and ether may be evaporated away, leaving the non-volatile constituents in the solid form. By whatever means the solvents are got rid of, the solid residue is washed in water, dried, and then redissolved in alcohol and ether.

Collodion processes of photography are still employed to a considerable extent in trade works, because they offer

many special advantages, and the bulk of the apparatus required and the extra manipulations become negligible in such establishments when economy and efficiency are considered. But the general tendency to replace collodion with gelatine, which has for nearly thirty years been complete so far as amateurs and portrait photographers are concerned, seems to be at work, surely if slowly wherever collodion remains in use.

CHAPTER VI

THE USE OF GELATINE

We have seen in the last chapter how the various operations in the preparation of sensitive plates suitable for getting negatives on, were gradually transferred from the individual plates to the bulk of material with which the glass was to be coated. Each step in this direction gets nearer to the possibility of making plates on the large scale commercially and so saving the photographer himself, not only from a great deal of trouble, but also from much anxious thought at the very time when his attention is needed for other matters. Another advantage of the production on a large scale is uniformity and therefore reliability, for each individual plate is no longer a separately made article with all possibilities of failure on its own account, but it is one of many all as alike as they can be made, and if a few of a large batch prove satisfactory, the probability is that the remainder are equally good.

About the time that we are now considering, a few years before and after 1870, the dried collodion emulsion was an article of commerce and dry collodion emulsion plates were also prepared commercially, though on what would now be considered as an exceedingly small scale. Dry collodion plates can still be purchased, or at least they were on the market a very short time ago, but their use is restricted almost entirely to the preparation of lantern slides.

On the part of photographers as a body, there was

for long after this time a distinctly adverse disposition with regard to commercially made plates and other sensitive material. There was a kind of feeling that a photographer ought to prepare his own plates, and that he was hardly fit to associate as a photographer with other photographers unless he did so. It took quite a long time for the very real advantage in the use of a commercially made article to be appreciated. It is difficult to understand this conservative attitude at the present time, when besides the advantages already mentioned, the gain in the quality of the materials is so obvious when a staff of workers can devote their whole attention to the making of them, and the large output renders it profitable to adopt elaborate precautions that would have been quite impossible with the man who made only the few plates that he required for his own use. But it must be remembered that the perfection of the processes for the commercial preparation of sensitive material was very gradual, and the methods at first employed did not differ from those adopted by the individual photographer, and it is possible that the man preparing plates for his own use tended to be a little more careful than he who prepared them for sale. This possibility is not a matter of photography but of human nature, for however honest and generous one may be, most of us are willing to take a little more trouble for ourselves than for other people. But the advantages of manufacture on the large scale gradually became so obvious that since some twenty years or so ago a photographer would no more think of making his own plates than of making his own cameras and lenses.

Except for a few special purposes generally in connection with trade work, collodion is now altogether supplanted by gelatine as the medium in which the sensitive salt is held. It was collodion that popularised photography, so that every one considered it his duty to have his portrait taken from time to time and give copies to

his friends, and tourists were not satisfied unless they brought home photographs of the objects of interest associated with the places that they visited. But it was gelatine that carried the development a stage further, and convinced millions of people how easy it would be to make their own photographs. This led to the production of a type of amateur photographer quite different from the original, who thought no trouble too great and no process too messy, so long as he succeeded. The new type knew nothing whatever about photography and cared nothing about it, he merely, as the Kodak Company expressed it, "pressed the button," and all the photographic work was carried out for him by a trade firm. Between these two extremes there is now represented every degree of interest and enthusiasm.

But the introduction of gelatine was like almost all other improvements in photographic work, very gradual. It was not so much that gelatine as a medium was a novelty, but rather what could be done with it. As collodion took years to supplant the Daguerreotype process, so gelatine took many years to oust collodion. Even when the superiority of a new method is demonstrated, the actual workers who have become skilled in the older method, are not very ready to change their habits and learn a new process.

It was in 1871 that Dr. R. L. Maddox published a formula for preparing a gelatine emulsion of silver bromide. It was a very imperfect process and hardly comparable with the gelatino-bromide process of to-day. Others were at work with gelatine and sought to make the use of it a commercial success, but they treated it, as was natural, after the manner of collodion, and sought to sell the emulsion or the dried emulsion—the pellicle; it was not yet that dry gelatine plates ready for use were offered for sale. The greater sensitiveness of some of these newer preparations, when compared with collodion plates,

proved a disadvantage rather than otherwise, as it caused many who tried them to fail on account of the disastrously long exposures that they gave.

Various improvements were effected in the use of gelatine, but the especial feature of the modern dry plate, that is its very great sensitiveness as compared with the plates prepared by any earlier process, dates from 1878. It was in this year that Mr. Charles Bennett, a member of the well-known firm of hatters and an amateur photographer of the early and enthusiastic type, exhibited some photographs taken with extraordinarily short exposures. His method was to keep the emulsion warm, or rather to prevent it getting quite cold (about 90° F.), for a few days, at longest about a week. Dry plates had been made and sold before this, for towards the end of 1877 they were advertised for sale by Mr. Kennett and also by Wratten and Wainwright, who supplied both collodio-bromide and gelatino-bromide dry plates. But at this time a wel-lknown authority writes: "Probably the final test of the excellence of a dry plate process will consist in its fitness for commercial sale, ready prepared for use, with some certainty on the part of purchasers that reasonable excellence may be secured in the use of such plates. This is a test, which, judging from the reports of the users of commercial dry plates, either no process, or no manipulation of any process, has yet stood satisfactorily." A year later, that is after Bennett's method of getting increased sensitiveness had been published, we find an experienced photographer who used both collodion and gelatine emulsions, always preferring collodion as being more easy and certain to work; which of course was natural, as the experience with collodion was considerable and gelatine was comparatively new. A noted photographer found Swan's gelatine dry plates to require from a half to a sixth of the exposure of a wet collodion plate, while Wratten and Wainwright said that their

F. Scamell

"PAPER!"

One of a series of records of "London Street Cries," some of which, that were common years ago, have now passed away.

gelatine dry plates needed only one-fifteenth of the exposure of a collodion plate, and in a poor light only one-fortieth.

Thus dry plates were gradually being improved, and in 1879 Mr. Joseph Paget offered a prize of £50 for the best dry plate process; the Paget Prize Plate Company was the result of this competition. Before the close of 1880 there were many makers of gelatino-bromide dry plates, the new industry had established itself, and it only remained to perfect it in details. It was soon found that a few minutes at the temperature of boiling water was as effective in getting greatly increased sensitiveness as a week at a temperature equal to that of a very hot summer's day in England, and Dr. Monckhoven found that by adding ammonia to the emulsion the heating might be dispensed with altogether.

Although by this time, 1880, the modern gelatino-bromide dry plate was being prepared commercially by many firms, they were prepared in much the same way that an individual experimenter would make a dozen or two for his own use. But the possibility of buying plates which needed absolutely no preparation to fit them for use, plates that could be taken from their package and put straight into the camera, and that would keep in good condition for weeks if not months either before exposure or between exposure and development, soon began to cause a great addition to the number of those who practised photography. The greatly increased sensitiveness of them as compared with collodion soon made them a necessity for the professional portrait photographer, for the possibility of getting a sufficient exposure in four seconds instead of forty or sixty, was too great an advantage both to the photographer and to his sitters to be neglected.

The demand for dry plates therefore gradually increased, and the need for machinery to take the place of

hand work soon began to be felt. But there was no machinery available for cleaning glass plates and coating them with a warm gelatinous mixture. Of course inventors were soon at work, but only experience could decide as to the efficiency of the apparatus devised. In October, 1888, the manager of one of the largest plate-making companies wrote to the author: "Up to the present all (our plates) have been hand-coated for the simple reason that we have not seen any machine which worked to our entire satisfaction until quite lately. Such a machine is now completed for us and we hope to have it in work in about a month. It coats very perfectly, and has at least two very desirable qualities, namely, it puts a measured quantity of emulsion upon each plate and none whatever on the back." Coating by hand means that the warm emulsion was poured from a tea-pot on to the plate held in the hand, caused to flow all over the plate by tipping it as required or by the use of a glass rod, that the plate was then put on a level stand until the emulsion had cooled and "set," and then dried. A coating machine would coat more than a thousand large plates in an hour.

Gelatine plates at the present time are all made in factories built for the purpose. Every precaution is taken to avoid dust, for dust on the plates means specks in the negative and this means spots on the print. For this reason large towns are avoided, and all the air that enters those parts of the factory concerned is filtered. Some idea of the effect of the filtration may be obtained from the fact that at a factory away in the country, it was observed that some of the men engaged in changing the filtering cloths were always ill after the operation, which was done once in three months. As soon as the connection between the filter cloth changing and the illness was discovered, the men were provided with suitable respirators and then their health did not suffer.

This indicates a very considerable accumulation of pathogenic germs on the filters as well as all the dust and soot and obvious "dirt." But even this is not sufficient precaution, and it is desirable to arrange so that there shall be no crevices or spaces that cannot be easily cleaned and that might therefore allow an accumulation of dust, and to wash the floor every morning. It will be understood that this indicates the general character of the precautions necessary, and that these will vary somewhat according to needs of different localities and the ideas of different managers.

Considerable difficulty was experienced at first in getting suitable glass. Plate glass would be much too costly, and sheet glass with a very uneven surface or with specks or other irregularities in it is obviously unsuitable. Good sheet glass being obtained, it is cut into pieces of the required size and any pieces that show flaws are rejected. The pieces of glass are then fed into a machine which carries them between moving brushes, over which a suitable cleaning liquid, such as a solution of carbonate of soda, is constantly flowing. They are carried through plain water to complete the washing, and then generally receive a coating of a dilute solution of gelatine containing chrome alum, so that when it dries the plate is covered with a very thin film of insoluble gelatine. This substance enables the emulsion film to adhere more securely to the glass. Without it the film might swell up away from the glass in blisters, or "frill" at the edges, or when dry it might come away from the glass or be peelable from it so readily as to be unsafe.

The prepared glasses are now fed into the coating machine, and are carried along on a continuous band under the trough that deposits upon them a liquid sheet of the warm gelatinous emulsion, and they are carried along continuously through a tunnel or the equivalent which is cooled by means of ice. The liquid emulsion

here sets to a jelly, and it is desirable that it shall set as quickly as possible to prevent the solid particles of silver salt from settiing down to the lower surface of the film. The plates are then stacked in racks and taken to the drying chambers where they are maintained at a warm temperature, which however is not warm enough to run any risk of melting the jelly. A current of filtered air passes between the plates and through the chambers until the coating is dry. The plates are then removed in their racks to be cut up, if the smaller sizes such as half-plate and under are required. Mechanical arrangements are employed as far as possible for this cutting, as it is done in the minimum of dark red light. The plates are then examined, and those that show defects are thrown out, and the remainder are packed for sale. All the operations from the coating with emulsion onwards are done in rooms lit with only a red light that is so feeble that any one going in from outside would probably be ten minutes or more before their eyes became sufficiently accustomed to the semi-darkness to enable them to see their way about.

The emulsion is prepared in large quantities and stored in jars. One of the methods of securing uniformity, is to make several batches as nearly as possible alike and to mix them, so that the general average may vary but little. Every ingredient has to be suitably pure, and as an amount of impurity that would be far too small for detection by any method of chemical analysis might interfere vitally with the quality of the emulsion, the suitability of each constituent is tested by making a small quantity of emulsion with it, using other ingredients of known quality, and testing a plate coated with the resulting preparation. This applies not only to the gelatine, which is liable to vary very much according to the method of its preparation and purification, but even to the nitrate of silver, which is a definite substance

and being easily crystallisable is supposed to be easily purified.

The principles involved in the making of a gelatine emulsion are exceedingly simple, and the practice is almost as simple when the most suitable procedure has been established. A portion of the gelatine is dissolved in water with the requisite bromide of potassium and a little iodide of potassium, for this latter is found to give certain desirable qualities that the bromide alone is deficient in. The nitrate of silver is dissolved in water and added to it. The insoluble bromide and iodide of silver are produced as a fine powder which permeates the whole solution, and nitrate of potassium is produced from the other constituents of the compounds. It is desirable, or rather it is necessary, to get rid of the nitrate of potassium together with the excess of the bromide of potassium present, and this is accomplished by cooling the emulsion until it becomes a jelly and washing the jelly in repeated changes of water. The rest of the gelatine is then added and the whole melted up together. It is well at some stage of the operation to filter the emulsion, as some of the silver salt is likely to clot together and form large particles which would give an irregular granularity to the negative made on the plate. For getting the enhanced sensitiveness the emulsion is heated as necessary before the main quantity of gelatine is added to it, or ammonia is used instead of the heating, or a combination of the two methods may be employed. No maker publishes exactly the method that he adopts, and probably there are little differences in the various factories, but so far as the user of the plates is concerned these differences are not very great. Some makers put more silver salt into their emulsions than others, some put thicker films upon their plates, some use harder gelatines, and there are other differences referring to the gradation that they yield that

will be subsequently considered. But the main difference to the ordinary user is in the sensitiveness, and this is not a difference as between one maker and another so much as between the various kinds of plate that each maker produces.

It might perhaps be thought that the greater the quantity of silver salt and the thicker the film the better the plate if the other qualities remain the same. But no such broad generalisation is justifiable. It is not unusual for an operator to be exposing plates all day, or as long as the daylight lasts, and then to develop his plates before going home. Plates with thick films take longer to wash than those with thin films, and if therefore he gives the same time to both sorts, the thinner films will perhaps be well washed while the thicker films will be imperfectly washed and suffer afterwards on that account. But will not the image on the negative be better for a liberal supply of silver salt, it may be asked. Even this does not follow. Many portraits are taken, especially of ladies and children, in which the whole subject is very light and shows very little contrast. If there is only a small difference between the darkest and the brightest parts of the subject, whatever it is, then a similarly small difference is all that is needed in the negative and more than sufficient silver salt, of course allowing a good margin, would only be in the way. On the other hand, a brilliantly lit landscape with a dark foreground, or an interior of a building in which a part is well lit and a part in deep shadow, needs a richly coated plate to do it justice. Hence it is desirable to prepare plates of different kinds for different purposes, as is customary, and it is well, where there is any doubt, to select a plate with a generous coating and make due allowance for the extra time necessary for its successful treatment.

Thus we have traced the very commencement of the

dry plate industry and to a certain extent its development. As the practice of photography has become increasingly popular and the applications of it have increased, the demand for gelatino-bromide dry plates has grown enormously. The number and the size of the factories have increased, and the author has been assured by one who is well qualified to know that the number of plates coated every day would now have to be counted in millions. There does not appear to be any method of getting exact figures, but certainly it is remarkable that an industry only thirty years old should have grown at such a rate as it has and is still continuing to grow.

With the introduction of systematised labour and machinery, and doubtless also the competition between makers, the cost of photographic plates has gradually been reduced; and if there is added to this the fact that at each change the intrinsic value of the plates has been reduced, we get some remarkable figures by tracing the cost of photographic materials during the last seventy years.

The price of plates has always been very nearly proportional to their size; it is sufficient therefore to consider only one size in order to get a rough idea of the expenses attending the practice of the art in its various stages of development. The quarter-plate, $4\frac{1}{4} \times 3\frac{1}{4}$ inches, dates back to the time of the Daguerreotype. One dozen silvered copper plates for this process cost thirty or thirty-two shillings if of the best quality, and inferior kinds were supplied down to as low a price as ten shillings. The amateur who was content with even this modest size must have found photography a costly pursuit when, instead of as we do paying a penny for a plate all ready for exposure in the camera, he had to pay half-a-crown for the plate, which he had himself to prepare by means of chemicals and special apparatus. But if he were content with paper negatives made by the calotype or Talbotype process or its modifications, the cost was really very moderate. Expensive

cameras then were unknown. Many were really nothing more than a box with the lens at one end and an arrangement for carrying the plate at the other, and the cost only a few shillings up to a pound or two. The various adjustments that we consider indispensable were only gradually introduced, and as in the Daguerreotype and wet collodion processes, only one plate could be dealt with at a time as it was prepared, only one plate carrier or "back" was necessary, and this for a single plate. The youth who made his own camera out of a cigar-box was really providing himself with the same type of instrument as was offered for sale at the photographic dealers. But this economy in the cost of the camera was pretty well balanced by the need for other apparatus, and the current expense was far greater than at the present time.

The glass plates used for the collodion process were about three shillings a dozen quarter-plate size. There were cheaper plates to be had and plenty of them were used, but there was a measure of risk in their want of flatness, uneven surface, and other defects. There was, however, a compensation for the high cost of glass plates, that if the negative was not satisfactory the plate could be cleaned and used again. At the present day it would cost more to clean and recoat spoilt plates than to use new glass.

In 1847 hyposulphite of soda was catalogued at five shillings a pound. In 1853 it was two shillings, the next year eighteenpence, and ten years afterwards fivepence. At the present time it can be obtained for less than twopence a pound, or perhaps a little more if bought in small quantities.

We must not close our treatment of the present subject without a reference to the use of films instead of glass plates as the support of the sensitive layer in the production of negatives. The earliest negatives were made on and to a certain extent in the substance of paper. The

irregularities of this material, as we have already pointed out, were constantly troubling those who used it, and the introduction of a separate substance to carry the sensitive compound that should be free from the structure of paper and under the photographer's immediate control, first albumen and then collodion and finally gelatine, was a very important improvement. As the substance of the negative, except the actual image, was required to be as transparent as possible, it was natural that glass should be used as the support for the sensitive film. A glass plate was not only the most transparent support possible, but, being rigid, it was easy to coat, easy to support in the camera, and every operation in the making of the negative and the getting of prints from it, was facilitated by its use. Being non-absorbent it could be easily cleaned and so freed from any impurities that would incur the risk of contaminating the sensitive material. At the present day glass still remains the best support so far as general manipulations are concerned, but it is heavy, bulky, and brittle, and in these details inferior to the paper used in earlier times. The advantages of paper were never forgotten.

A flexible film is so superior in portability to glass, that as early as 1854, that is in the first days of collodion and while the Daguerreotype process was still being worked, a roller slide was designed by A. Melhuish, that is an arrangement to slide into the back of the camera, and containing two rollers between which the sensitive film that is ready for exposure is stretched. By having a long band of film wound on one roller it can be transferred gradually to the other as needed for bringing a fresh portion into position for exposure. Thus a series of almost any number of exposures might be made without the need to use a dark room for changing the sensitive material. This method of working was popularised by the Eastman Kodak Company in 1885. In their cameras,

the rollers are detachable bodily from the apparatus, the film as wound upon the roller by the makers is slipped into its place, and when it has been exposed, the receiving roller is turned several times so that a length of black paper attached to the end of the film shall be wound round it to protect it from the light, and is then removed for development, &c.

Many sorts of films were devised, some of them for working on rollers, others thick enough to stand alone like glass, others were arranged like drawing blocks, so that each as exposed might be stripped off leaving the next ready. Gelatine, collodion, varnish, and paper in various forms and combinations were used to make the films of. Some of the films were held on temporary supports such as paper, from which they had to be removed after exposure and development. Some had sensitive emulsion on both sides, so that any granularity due to the material of the film might not appear in the finished negative, as any unduly thin or transparent part would be neutralised by the light passing through it and giving a deposit, when developed, on the back film.

The rollable film that is at present so largely used is of celluloid, which can be obtained free from structure and almost as transparent as glass. It is coated on one side with the sensitive emulsion, and to counteract the tendency to curl or roll up when wet, a thin layer of gelatine is put upon the back surface. This kind of film was introduced in 1903 by the Kodak Company, and is in general use.

CHAPTER VII

THE PLATE

The first question that arises in connection with the plate is—how sensitive is it? The duration of the exposure necessary to produce the desired effect must depend upon this, and therefore the degree of sensitiveness of the plate must be known in some way or other. Now sensitiveness is not an absolute matter, it may be compared to a measure of length or capacity, in order to express which it is necessary to adopt a unit. If we say of any object that it is three feet long, we only mean that it is three times as long as a certain distance which is called one foot and is adopted as the unit. A person who does not know the length of one foot, can ascertain it with a sufficient accuracy for practical purposes by buying a foot rule at a tool shop. A scientific man who wants to be more exact can gain access to a standard measure which is carefully preserved for the sake of reference. This standard foot is a purely arbitrary measure, it might just as well be a little longer or a little shorter, it would not matter at all what it was so long as it was definite, and known to those who wished to use it. The French metre is rather longer than our yard and bears no simple relationship to it, but it is just as serviceable on the Continent as the yard is in England, because every one concerned knows what it is.

It may seem at first sight just as easy to fix on and adopt a unit or standard of sensitiveness as a standard of length, but the two cases are widely different. First, it

would be impossible to preserve a standard sensitive plate because of its liability to alter. Further, every time a comparison was made with the standard plate a part of one would have to be used up, and this would necessitate a number of standards with their unavoidable variations. And there are still other difficulties. The word sensitiveness implies sensitiveness to something. To light, may be answered—but to what light? is a most vital question. It is not uncommon to find at the present time a plate more sensitive than another to daylight but less sensitive to gas light. Whatever light is adopted, the particular degree of sensitiveness will apply to that light only. All ordinary lights are complex mixture of radiations of many wave lengths, and the very essence of a standard should be simplicity. Again, the way in which a plate is treated, as in development, may affect its sensitiveness, and suppose that a certain standard treatment were adopted, and this has actually been proposed, and a plate was made which by some other treatment was far more sensitive than by the standard treatment, the standard sensitiveness estimation would count for nothing. Who would care to know that a plate was no more sensitive than another when tested by a "standard" process, when it was, say, three times as sensitive if treated by a method better suited to it?

Sensitiveness cannot be definitely estimated unless the conditions under which the plate is to be used are exactly expressed. Although it is necessary and possible to give a general idea as to whether a plate is slow, or rapid, or extra rapid, &c., it is not possible to do more than this unless the conditions of its use are specified. In commercial statements as to sensitiveness daylight is assumed to be used unless the contrary is distinctly stated, and the makers of plates often express the sensitiveness by figures. The figures given by the same maker may be more or less comparable among themselves, but it does not at all follow

that the same figure or expression given by different makers indicates the same sensitiveness.

The methods of estimating sensitiveness at present employed may be divided into two classes. The earliest is also the most obvious, and although much has been said against it, it must always remain of value. It consists in arranging a graduated series of exposures so that the least shall be small enough to give no result with the most sensitive plate to be tested and finding out the very smallest exposure that will give a result on each of the various plates to be tested. If one plate will give its first indication of a result with an exposure that is one-tenth of the exposure necessary to begin to affect another plate, it is obvious that it is ten times as sensitive as the second plate.

The light used for this purpose must not be subject to change, therefore no domestic lamp, gas, or electric light will serve. It is most usual to employ a definite and pure liquid or solid, or a pure gas such as acetylene, and arrange for its combustion so that the flame shall always be of the same size. Sometimes an opaque screen with a hole in it is put in front of the flame in order that only that part of the flame that is least liable to alteration may be used. The series of exposures may be made by putting the plate far enough away from the illuminant and uncovering it a part at a time for say one, two, four, eight, &c., seconds, or the period of the exposure of the various parts may be the same, and the plate may be brought nearer to the illuminant in order to increase the exposure effect, but it is usual to save time and trouble by putting it behind a screen that graduates the light. Such a screen may be of the same size as the plate and have a series of squares upon it of increasing opacity, or other means may be adopted to secure a similar effect.

The drawback to such methods of estimating sensitiveness is, that in ordinary photography the very thinnest

deposits that can be produced upon a plate by the feeblest light are rarely of any use, because they are so thin that no difference can be seen in the print between them and the parts where there is no deposit at all. They have, as is said, "no printing value." And it may happen that a plate that is considerably more sensitive than another by this method of estimation, will need even a longer exposure than the apparently less sensitive plate in order to get an equally good negative of an ordinary subject. The first plate shows a long series of feeble deposits under the increasing opacities of the screen, which cannot be utilised in ordinary work.

To avoid this, Messrs. Hurter and Driffield proposed to neglect altogether these thin deposits given by the feeblest lights and to consider only those densities that are of actual use in ordinary practice. But although these thin deposits are of very little if any use in the photography of ordinary subjects, they may in other cases be of the greatest importance, as for example in the detection of a very feebly luminous object, such as a nebula or a star.

An unqualified statement of sensitiveness can never do more than give a general and vague idea of the character of the plate. If more than this is wanted the plates to be compared must be tested under exactly the same conditions that will hold when they are to be used, and if not on the actual subject that they are required for, at least on a subject of an exactly similar character. The way in which the comparative sensitiveness of plates may vary even when using the same kinds of illumination, may be illustrated by experiment. Suppose that the object to be photographed remains without change, that the light is in no way altered, and that the lens and the camera and their position relative to the object remain exactly the same, then if a certain plate, which we will call A, requires an exposure of one second to

Edgar Pickard

THE VAULTING-HORSE

The estimated exposure given in taking this photograph is the one four-hundredth part of a second. The movement here is comparatively simple as the athlete's body moves as a whole.

give the negative required, while another plate, which we will call B, needs an exposure of only the half of a second to give the same kind of negative, then we should say that the plate B is twice as sensitive as the plate A. We may now, without going outside the range of practical conditions, imagine that we have another plate, C, which is sufficiently exposed under exactly the same circumstances in the one-hundredth part of a second. This plate, C, will be said to be one hundred times as sensisive as plate A. As sensitiveness is a purely practical matter, we have now before us three plates with sensitivenesses, under the given conditions that may be definitely expressed in figures as plate A, 1; plate B, 2; and plate C, 100. Suppose that the object was illuminated by a cluster of one hundred lamps so arranged that the light from each shone upon the object from the same distance and without hindrance, no lamp hidden or partly hidden behind another, we have by this arrangement an opportunity of definitely controlling the amount of light that illuminates the object, or, as we should usually say, of controlling the brilliancy of the light. It is perfectly obvious that if fifty of the one hundred lamps are put out, there will remain a half of the original light, and if ninety-nine of the lamps are put out so that only one is left, the brilliancy of the light will be exactly one hundredth of the original, supposing as we do that all the lamps are of exactly equal illuminating power. In this way we can easily imagine how we can definitely regulate the brilliancy of the light that falls upon the object.

Let us imagine that the experiment is tried of putting out half the lamps, and doubling the exposure given to each of the plates in order to make up for the deficiency of the light, half the light for twice the time, and we shall probably notice very little difference in the comparative sensitivenesses of the three plates. But if the

light is further reduced, if ten lamps are employed instead of the full one hundred, and if the periods of the exposures are multiplied by ten in order to compensate for the reduced light, then the three negatives that result will not be alike, the slower plates will appear to be less sensitive than they were at first. Now extinguish all but one lamp so that the light is only one-hundredth as powerful as at first, and make each of the exposures one hundred times as long to compensate for the reduction of the light. In this case the negatives on the slower plates will be obviously under-exposed, and the most sensitive plate will perhaps show a little inclination in this direction. Under these conditions the apparent sensitiveness of plate C will have gone down a little, perhaps too little to notice it, while the sensitiveness of plates A and B may appear to be reduced as much as to the half of what they were at first. That is as compared with the plate C, instead of needing fifty and one hundred times the duration of exposure to give the same kind of negative, they may need approximately one hundred times and two hundred times respectively.

It is therefore just as true to say that plate C is two hundred times as sensitive as plate A, as to say that it is one hundred times as sensitive; the fact is that each statement is only a partial truth, and that the comparative sensitivenesses of the plates as expressed is true only when the conditions under which they were tested are reproduced. In the experiment that we have first described, all the lamps gave an equal amount of light, but it is clear that the effective change produced in the slower plates by a single lamp was no more than half as much as the effective change that each individual lamp produced when they were all working together. It is as though the silver bromide did not like being interfered with, and that its power to resist had to be broken down before it could be changed into the less stable or developable condition.

When this resistance has to be overcome by one lamp it is very obvious in its magnitude, and uses up in this case as much as half of the power of the light given by the single lamp.

If now, while the struggle between the light and the silver bromide is going on, the light is withdrawn, we might expect the silver salt to recover its original condition to a certain extent, so that the light would, on being allowed to resume the struggle, work at an additional disadvantage, as it cannot go on with its action exactly where it left off. The plate will then appear to be less sensitive than before, because for the same effect it will need a greater amount of light when this falls upon it intermittently. This apparent loss of sensitiveness in the plate increases, as might be expected, as the light is made more feeble and as the number of stoppages in its action is increased. In one series of experiments made by Sir William Abney in his investigation of this matter, he found that only half the effect was produced with exactly the same total duration of exposure, when the exposure was divided into twenty-eight thousand separate parts by the rotation of a screen with holes in it in front of the light. If we may apply the nomenclature of wind to light, we might say that twenty-eight thousand puffs are only half as effective as one long blow, although exactly the same amount of light impinges upon the plate in the two cases.

A given quantity of light may have its effect reduced not only by being made unduly feeble, or by being much subdivided, but also by being too intense or concentrated. A suitable electric spark will give a very powerful light but of very short duration, and therefore highly concentrated, and Sir William Abney found the same amount of such light when made sixty-four times more intense but allowed to act for only one sixty-fourth of the time, produced less than one-quarter the effect. In this case the more

sensitive plates showed the greater discrepancy, while with an unduly feeble light it is the slower plates that are most affected by the exceptional conditions. Whatever may be the cause, therefore, an extreme variation in the intensity of the light in either direction, or in its subdivision, causes a loss of its efficiency in its action on sensitive plates, although the total quantity of light concerned remains exactly the same, and this loss is different with different plates.

Change of temperature also affects the sensitiveness of plates, warming increasing it and cooling decreasing it. The loss of sensitiveness produced by extreme cold, as by the evaporation of liquid air, is not so great as one might expect from the changes that result from an alteration of temperature within the small range of forty or fifty degrees centigrade that we are subjected to during the changing seasons. But this subject needs further investigation.

Thus we see that almost every variation of circumstance affects sensitiveness of plates and different plates to different extents. Sensitiveness is not an inherent quality of the plate, and it cannot be expressed by a definite figure any more than the strength of a man can be so expressed. We call one man strong and another weak, and we know what is meant. So we may say that one plate is rapid and another slow. We may say in general terms that one man is able to lift twice as heavy a weight as another man. So we may say in an equally vague way that one plate is twice as sensitive as another. But it would be absurd to attempt to find the exact weight to a pound that two men could each lift in order to express their relative powers in exact figures. If such an experiment were made it would only express their relative strengths under those particular conditions, and a very different result might be obtained under other conditions. And the relative sensitiveness of plates is just as indefinite.

The importance of the exact estimation of sensitiveness

is often much overrated so far as ordinary work is concerned. It is doubtful whether any photographer employing plates for general purposes could detect a gain of 25 per cent., and indeed a difference of 50 per cent. would often pass unrecognised. It may be taken as a general rule that if a photograph shows signs of too short an exposure, it is not worth while to increase the exposure next time to any less proportion than double the first. Expressing the same fact in terms of sensitiveness instead of exposure, if a plate is not "quick" enough for any given work, it is rarely of use to try a plate that is not at least twice as sensitive.

We may now very well ask, What is the nature of the sensitiveness to light in this case? What change does the light produce, or what is the difference between the plate before and after exposure? In order to answer these questions, we must endeavour to get a mental picture of the plate and its various parts.

If bromide of potassium and nitrate of silver are separately dissolved in water and the solutions are mixed, a yellowish insoluble substance will be produced, which being insoluble will render the liquid milky or opaque, and will eventually, if left to itself, settle down to the bottom of the liquid. The change that takes place is of a very simple character, it is merely that the silver takes the place of the potassium and the potassium the place of the silver. The insoluble substance is bromide of silver, and the nitrate of potassium produced remains in solution. It is this change that takes place in the preparation of a gelatino-bromide emulsion; but gelatine is also present in the solution, and this causes the bromide of silver to be produced in rather smaller particles and tends to prevent it from settling down. To keep the gelatine liquid the solutions are warm, and when the mixture is cooled it sets to a jelly. This is washed to get rid of the nitrate of potassium and the small excess of bromide of potassium,

treated as before described to make the silver salt more sensitive, and then melted and spread upon the glass plates. There is generally a little iodide added as well as bromide, and it is possible that sometimes other things may be put in, but nothing further is essential. For simplicity's sake we will disregard the iodide and other possible additions.

The sensitive plate, therefore, consists of a film of gelatine on the glass, and throughout the gelatine there are distributed small particles of bromide of silver. These particles are very small, they are not of any particular shape, and they make the gelatine film appear milky. It is these particles that are the sensitive compound, and they exceed by very far the sensitiveness to light of any other known substance. In the following consideration of the plate, it is desirable to clearly imagine the transparent gelatine film containing these fine particles of bromide of silver fairly evenly distributed through it.

Before regarding the plate as a whole, we will imagine that we have only one of these particles and allow light to act upon it in repeated small doses, so that the change at every stage may be noted. Bromide of silver consists of two substances, bromine and silver, combined. As is usual when substances are really combined as distinguished from being simply mixed together, the properties of the individual substances are no longer apparent. Bromine is a brown heavy liquid of extremely unpleasant and choking odour, and silver is a white malleable metal. Bromide of silver is not brown, it has no odour, and it is not metallic in any of its properties. The changes that such a substance can undergo are not very varied. Its composition may be changed by a separation or a partial separation of its constituents, or by adding some fresh substance to it, or it may be altered in its nature without any change in its composition by a variation of the relationship that exists between its various parts. The

molecules of silver bromide may, for example, be grouped together in a different way or to a different extent. Bearing in mind these possibilities, we will get what information we can as to the action of light upon one of the particles, which of course must contain in it a very large number of the molecules of the compound.

By using a feeble light and allowing it to act for a very short time there is no recognisable change effected in the particle. There must be a change, because if the silver bromide were in exactly the same condition as before it was subjected to the action of light, then another small dose of light would still leave it as it was. But this is not so, for by allowing the light to act a little longer, there is no difference in the appearance of the particle, it is impossible to detect any separation of its constituents or the addition of anything to them, but the compound is now distinctly less stable than it was before. It is possible to prepare a solution that has a tendency to take away the bromine and leave the silver, and to so adjust its power that if the particle that has been acted on by light is put in it its bromine is taken away and only the metal silver is left, while a particle that has not been acted on by light will remain in the solution unchanged. This method, and a variation or two of it, is the only known way of discovering the difference between an exposed and an unexposed particle. The light has shaken the particle, or the molecules of it, into a less stable condition.

If a little more light were allowed to act on the particle before it was tested, it would be found to be still less stable, or more ready to give up its bromine to the solution that is ready to take it. But if the light is allowed to continue its action a few stages further, the particle begins to grow more stable again, until it reaches a condition in which it vies with the original unacted on compound in its power to resist the loss of its bromine.

The exposed and the unexposed particles cannot now be distinguished by this method; they may be compared to two men racing round a track, one of whom has "lapped" the other. To the casual observer the two men are level, but if he waits till the end of the race he will discover the difference. By allowing more light to act upon both the particles it will be easy to tell that one was a stage in advance of the other.

After the particle has by the continued effect of light upon it become unstable and stable again, if light is allowed to act upon it still further another change takes place, it seems to become unstable again, or it may be that the light itself now separates the bromine from the silver, as we know it is eventually able to do under suitable circumstances. Very little is known about this further change, and it may perhaps be of a different character in different cases.

Now we must return to the gelatine film that contains these particles distributed thickly through it, and bearing in mind that the particles are not all equally sensitive, endeavour to trace the effect of light upon it as a whole. It will save circumlocutory phrases to say at once, that any solution that is able to take the bromine away from the silver bromide that has been acted on by light and not from the bromide that has not been exposed to light is called a "developer," because it develops or brings out or completes the formation of the image. Although the particles are not all equally sensitive, the greater number of them are very nearly so, and there is a small proportion of less and a small proportion of greater sensitiveness. We will suppose that light acts in repeated increments upon the surface of the plate, and that the effect of its action is investigated by the application of a developer. As the light comes upon the surface it is there that its effect must begin, and therefore after a small exposure the more sensitive particles near the

surface will be rendered amenable to the action of the developer, while the bulk of the particles will be affected only to an extent that is insufficient to render them attackable by it. Further action of the light will show its results deeper into the film, the more sensitive particles lower down and a much greater number nearer the surface becoming unstable. With still more light the number of particles that can be developed will increase, always in greater number near the surface than below, until the light has acted sufficiently to begin to cause the reverse change in the most sensitive particles that lie near the surface. These become stable again, and if there is an equivalent number of the less sensitive particles remaining, there may be for a certain time as many brought into the unstable condition as are rendered stable again by the excess of light action. But eventually as the light action increases the number of the particles near the surface that are unstable diminishes, and this effect gradually passes through the film. Therefore, considering the film as a whole, the gradually increasing effect of the light first increases the number of the particles that are rendered unstable and then diminishes it. And if we look at the opacity of the deposit as a whole instead of the number of particles, we see that this also will gradually grow first greater and then less as the action of the light increases. The proportions of particles of various sensitiveness, and possibly other matters, will affect the relative rates at which these changes take place.

So far as the effect in the plate is concerned, any object that is photographed is nothing more than an assemblage of patches of different shapes and different brightnesses. In the image that falls upon the plate in the camera there is the same disposition of parts and the same range of brightness, if it is truly produced. The exposure of the plate is, of course, of the same

duration for every part of the image, and it is the varying brightness of the different parts that causes a different amount of light action on the different parts of the plate and so leads to the production of the image in the negative. What is wanted is that the amount of change produced in any part of the plate, which may be regarded in general terms as the number of particles changed into the unstable condition, shall vary in accordance with the brightness of the image that falls upon that part.

We are now in a position to understand the effect of too little or too much exposure, and we will begin, as in the previous cases, with a small exposure to trace the effect as it is prolonged to a very much greater extent than it is ever likely to be in practice. It is the time of the exposure that decides the extent of the action. With a very short time, the brightest parts of the image will have produced a considerable change and a satisfactorily proportional one, but the parts of medium brightness will have fully affected only the few unduly sensitive particles, and the duller parts of the image will not have been able to do even this much. The developed plate will show the high lights well, but the middle tones will be feebly represented, and the detail in the darker parts of the subject will not be shown at all—where they should be will be a blank. A print from such a negative would show the dark parts of the subject as uniform black patches, and the detail in the middle tones would be lacking in contrast—"flat." By prolonging the exposure somewhat, the brightest parts of the image produce correspondingly more effect, the middle tones take their proper place, but the darkest parts still have not had time enough to act on more than the small proportion of the unduly sensitive particles, and although the detail here is visible, it is weak and flat. This is under-exposure, and in the first case the under-exposure is exaggerated.

By giving a longer exposure the brightest parts and the middle tones continue to give an increased effect and the darkest parts now take their proper place. This is correct exposure, and the print from the negative, if both are properly made, will give the most true representation of the object that is possible under the conditions that hold. By prolonging the exposure all parts will continue to increase the action that they effect, and the negative will still give a good print, but being denser all over, it will take longer to get the print. There is thus with a good plate, that is, one that has a liberal supply of emulsion, and an average subject, always a certain range of exposures that will give a good and true negative. There is a minimum and a maximum exposure between which the errors resulting from both under and over exposure are avoided. What this range is, clearly depends on both the plate and the subject.

If now the exposure is prolonged still further, the brightest parts of the image will have acted on all the particles in that part of the plate that they fall upon, or, if the film of emulsion is too thick for this to take place, the particles in the surface of the film will have been so much affected that they will be beginning, the most sensitive of them, to assume the more stable condition. In either case, the effect of the brightest parts of the image will cease to increase with the prolonged exposure at the due rate, and therefore the contrast here will diminish, and in the print the detail in the high lights will be flat and weak. The other parts still retain their proper proportional relationship to each other. By still increasing the exposure this flatness extends to the less bright parts and eventually perhaps to the whole image. With a still further prolongation of the exposure, the brightest parts will change an increasing number of particles into the second stable condition, and so will produce a diminishing instead of an increasing effect,

and the highest lights may thus appear in the print as if they were actually less bright than those parts of the image which are really inferior to them in brightness. This is "reversal," and is the natural effect of great over exposure. It is possible to push on this reversal until it is complete, and instead of a negative where the highest light is represented by the densest deposit, the result is a positive with the densest deposit standing for the darkest part of the object. The getting of such a result satisfactorily needs special precautions, and as it is always uncertain, it is not a method of work that is to be recommended. Sometimes it would be economical and time saving, but it has been tried and experience always condemns it.

CHAPTER VIII

THE EXPOSURE

A CAMERA is literally a *chamber*, and a camera obscura is a *dark chamber*. The words as applied in photography are not well chosen, for there need be nothing specially chamber-like in a camera, and it is dark only when it is not in use, for it is light that does the work. A small chamber is more or less of a box, and it is not uncommon to speak of a "box" camera to distinguish it from a bellows collapsible camera. In America a camera is often called a "box."

This chamber or box idea is misleading to those who do not understand the subject. It was rather by accident than otherwise that some of the earliest photographic cameras were box-like in outline, and it is not desirable to emphasise this similarity because it draws attention from the actual nature and use of the instrument. A camera should be regarded rather as a stand or support, because its true function is to hold the lens and the sensitive plate in that relationship to each other that the photographer desires. The tubes of a telescope play the same part with regard to that instrument; they support the object glass at one end and the eyepiece, with which the image is viewed, at the other. In the case of the microscope stand, the object to be viewed also has to be supported, and this leads to a measure of complication. But so far as the optical part of the apparatus is concerned, the only adjustment wanted in both the telescope and the microscope in their simple forms, is the power to alter the distance between

the object-glass and the eyepiece so that the image may be clearly seen, or, as we say, that it may be focussed. The earliest cameras also were provided with only this adjustment, as photography was such a novelty that the mere getting of an image of a passable quality satisfied the worker.

In Fig. 20 three old cameras are shown as they were made during the first ten years of photographic practice immediately following the introduction of the Daguerreo-

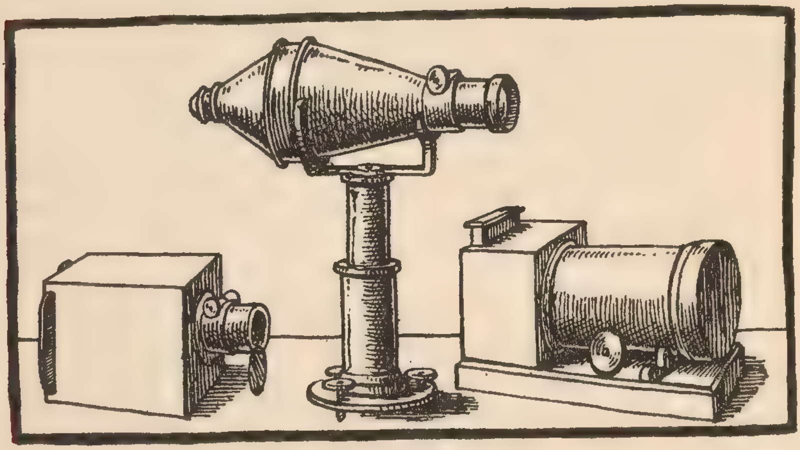


FIG. 20.—Early types of cameras.

type and Talbotype. The first drawing shows one for taking photographs on paper. It has a meniscus lens carried in a tube that slides in its fitting for the purpose of focussing. The next is by Voigtländer and is obviously designed on the simple telescopic plan. The body of the instrument is made of round brass tubes, some conical to give the increase in size necessary to accommodate the plate. The shorter conical portion that extends behind the plate carries a small lens through which the observer can see when he has got the image in good focus. The third camera has a very large portrait lens, desirable at that time in order that the exposure might be shortened, and

it extends only two or three inches behind the lens and is otherwise small, because the defining power of a lens of such a large diameter was limited to a very small area. In all these cases there is the simplicity of the ordinary telescope, the variation being merely that the part that is to take the plate or the sensitive paper is made larger in order to properly accommodate it.

In a small guide to the practice of photography, published in 1854, we read that the sides of the camera may with advantage consist of a "bag of cloth or caoutchouc" stretched between the back and the front. We further read that "instead of, and even in preference to, the cloth or caoutchouc bag camera, one of pasteboard may also be used, made in the same shape as the bellows of an accordion." By 1860, or about then, the bellows were sometimes made tapered towards the lens, so gaining in lightness and compactness. Thus we see how varied was the "box" part of the camera—it was made of all shapes and all materials, its only duty being to keep out extraneous light, so that the image produced by the lens might be received by the plate in its full brightness and purity.

Let us endeavour to see what the modern photographer wants his camera to do, bearing in mind that it is very desirable, indeed we may say necessary, that the lens shall produce a greater extent of image than is sufficient to cover the plate. In order to cause the image to conform to the rules of plane perspective, it is necessary that the plate shall be vertical when photographing fixed objects or those that are to be represented in their natural positions. For if the plate is not vertical, the scale of the image, that is its dimensions compared with the dimensions of the object, after making due allowance for the different distances of the various parts, will decrease in the direction of that part of the plate that is tipped forwards nearer to the lens. So far as the scale is reduced, vertical and therefore parallel, lines in the object will be represented as

if they inclined towards each other. This may be seen in beginners' attempts when they point their camera upwards to photograph a high object and make no counteracting adjustment; the building is represented as tapering upwards instead of with its sides parallel.

If then we start with the plate vertical and the lens exactly opposite the centre of it, the image of the horizon will fall across the very middle of the plate. It is very rarely that it is wanted in this position. If we are photographing a building that is chiefly above the horizon we do not want the photograph to show the house entirely in the upper half of the picture with the lower half occupied by an expanse of uninteresting foreground; and if the aim of the photographer is to get a beautiful expanse of level country, he does not want an exactly equal expanse of sky above it. Truly he might cut off from the print what he does not want, but that would mean wasting nearly half of the plate in each case, besides having to carry about a camera of nearly twice the dimensions really necessary for the work.

The most obvious method of meeting this difficulty would be to provide for the movement of the plate up and down, so that by adjusting its position the photographer should be able to place it where it would receive exactly that part of the image produced by the lens that he wished for. But this would mean a large and correspondingly heavy camera, and as we know that it is simply a question of the relative positions of the lens and the plate, moving the lens in the opposite direction to the required movement of the plate would have the same result. The horizon is level with the lens, so that by raising or lowering it the position of the horizon on the plate can be regulated. The drawback to this substituted method of adjustment is that the lens is the point of view, and shifting the point of view an inch or two, while negligible under ordinary circumstances, may be undesirable with near objects.

But if the object is very high and comparatively near, the camera may have to be pointed upwards in order to get the image on the plate at all. For the sake of correct "drawing" it is necessary next to restore the plate to the vertical position, and this requires that the part of the camera that carries the plate shall be made to swing like a toilet looking-glass. Hence the need for a "swing back."

The image given by the lens may be too small, so that the plate receives the representations of things around it that are not wanted. A lens of greater focal length will give the image on a larger scale, but then to focus it the plate must be brought to a greater distance from the lens—there must therefore be ample focussing adjustment, or range of length, in the camera. For a similar reason, but in the opposite direction, it is necessary to be able to push the camera "back," with the plate it carries, near up to the lens. For some pictures the longer dimension of the plate must be perpendicular, for others horizontal; if therefore the camera cannot be turned bodily on to its side, and with any but the smallest cameras this is not desirable, the back that carries the plate must be made square and "reversible," that it may be attached to the camera in either position.

All camera adjustments are of the type of those mentioned and refer merely to the relative positions of the lens and plate, and therefore have no direct influence on the quality of the photographs produced. A simple box of cardboard that would hold the plate and lens firmly in position would give as good a result as the most costly camera, but it would be inconvenient, because in the next photograph a different arrangement might be necessary and with a non-adjustable apparatus it would be impossible to make the change. From this point of view these adjustments are necessary, and the manner in which they are provided for at the present

time is indicated in Figs. 21 and 22, of two cameras by Messrs. Watson & Sons. The "Acme" with its taper-

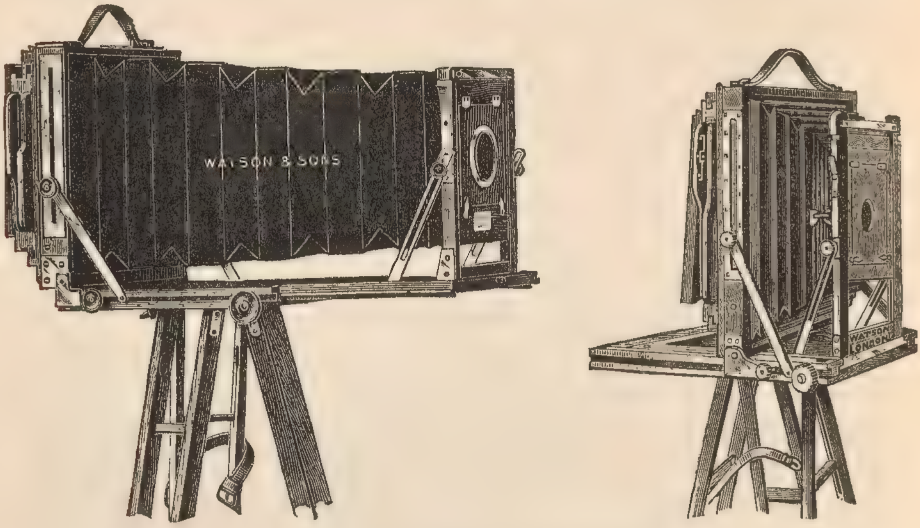


FIG. 21.—Watson's "Acme" camera.

ing bellows folds up into a small space and is light, while the "Premier" with its full size and fixed front is heavier,

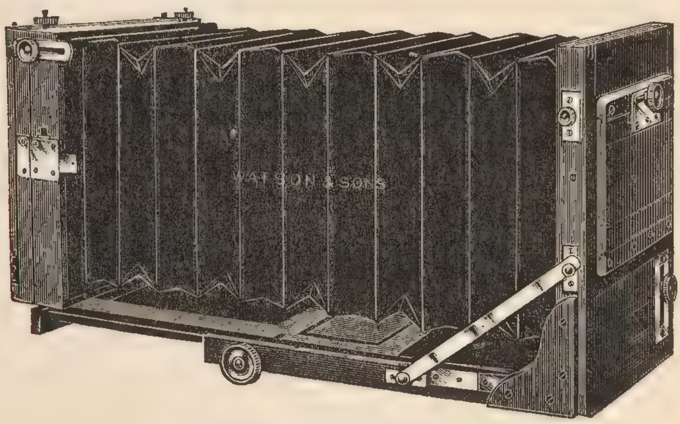


FIG. 22.—Watson's "Premier" camera.

but to be preferred in some of its details. Excluding hand cameras, which will be subsequently considered,

these are the two standard types for work out-of-doors, with of course many variations in details according to the individual maker.

For photography indoors the requirements are different. The professional portrait photographer does not want portability beyond the power to wheel his stand and camera about his studio. The necessary range for focussing is more limited, he generally uses a larger and much heavier lens, and he wants to quickly insert the plate after focussing so that he may not inconvenience the model. His apparatus may be heavy, but it must be such that he can quickly and easily manipulate it. The trade photographer often needs cameras that will take very large plates for copying work, and here again details are varied to suit the special requirements of the case. It is obvious that the most convenient apparatus for a plate four or five inches long may not be suitable for the manipulation of a heavy plate two or three feet long. But the general principles remain the same whether the camera is as small as the hand, or is so large that the operator can get right inside it in order to focus and adjust the image.

Work indoors is generally more under control than work out-of-doors, and therefore is preferable when the object to be photographed is movable and other circumstances permit it. It is not only that adverse climatic conditions, such as wind and rain, are excluded, but that the light that illuminates the object may be adjusted to the best advantage, by means of blinds or shutters to exclude or modify it as desired. An apartment devoted to this kind of work is called a "studio."

A studio for trade work, that is copying, enlarging, and such photography as is required for the making of printing blocks and plates, would perhaps be better described as a photographic workshop, for there is nothing to consider in its arrangements but the efficiency of the work, and therefore it is full of the necessary apparatus.

The earliest portrait studios were arranged on somewhat similar lines : everything was subservient to the photography, and the person to be photographed was treated very much as if he were an inanimate object to be operated upon. Indeed the photographer himself was called an operator, and there is no wonder, therefore, that when the novelty of having a picture of one's self produced automatically wore off, and people went to the photographers to please their friends rather than themselves, that they should feel as if they were going to have something done to them, and compare their visits to the photographer with their visits to the dentist. In both cases there was a special kind of chair and an arrangement for steadying or holding the head, and the light was specially managed to illuminate the sitter. The similarity was much greater than those of the present generation can realise. The studio was too often lumbered up with a multiplicity of paraphernalia — backgrounds, head-rests, screens, peculiar uncomfortable and almost indescribable pieces of furniture, some of which could be changed by a little alteration into something of quite a different kind. There might be things made to imitate a fence, a stile, or a balcony, mats to imitate grass, an imitation boat, or rather half a boat, because as the other side would not be seen there was no need to have it. The idea was to be able to imitate in the studio any scene either indoors or out-of-doors. Now imitations of outdoor scenes in a room are always incongruous. The light that falls upon a person in a building is restricted as to its direction, and this causes a greater difference in brightness between the side next to the light and the side away from it, and, if well managed, a better appearance of roundness and modelling than is often possible in the open air where the light comes more equally from all directions. An indoor lighting of the figure with outdoor scenery must always be false.

E. O. Hoppé

A View in Mr. Hoppé's Studio

The Exposure

The early portrait studios had to have a great deal of glass, because the necessary period of the exposure of the plate was long enough to make it desirable to do everything that would tend to shorten it. They were made of many shapes. Some were tunnel-like, with an expansion at one end to accommodate the sitter, others were large apartments with huge skylights, but the same idea was manifest in all, namely to get effective lighting and to get as much light as consistent with the result desired that the exposure might be shortened.

As the manufacture of more sensitive plates became possible, as the novelty of being photographed wore off, and as portrait photographers grew to understand their business better, they began to think more of those who patronised them, instead of being absorbed in the simple manipulative part of the work. The sham properties gradually disappeared, and now in the best studios all the furniture is of approved patterns, solid, and good, and all the appointments are such as tend to please the eye and conduce to comfort. A good modern studio is comparable to a drawing-room rather than to a workshop, and the skilful portraitist now finds no need to ask his sitter to assume any particular expression. The air of artificiality has given place to an atmosphere of truth. By the kindness of Mr. E. O. Hoppé we are able to give a photograph of the studio that he has recently opened at 59 Baker Street, London. Those who visit Mr. Hoppé for the first time are loath to believe that this is really his studio, for it is nothing more than an ordinary large room on the first floor of the house, with three large ordinary windows that face the street. Nothing of the character of photographic apparatus is evident, and it is not until the visitor has settled himself comfortably and naturally and is obviously at his ease, that the camera is brought in and the exposures made. Mr. Hoppé has favoured us also with an example of his work.

But whether it is a person or an inanimate object that is being photographed, the actual photography is much the same. The image formed by the lens has to be allowed to fall upon the plate for a suitable time. There is a little licence, a little difference between the minimum and the maximum for the best result, but if these limits are overstepped in either direction the result suffers. This range of exposure is considerably longer than some workers make believe. We may sometimes hear such an expression as, "I told him to give twenty seconds and he gave twenty-two, and the exposure was just those two seconds too long." Such a statement as this is not true, because a difference in the exposure time of one in ten is not detectable to the unassisted eye either in the negative or the print. If the twenty-two seconds was obviously too long as exposure, it is fairly certain that eleven seconds would have been better, and probably a difference midway between these would have been the very least alteration of the time that would have been recognisable in the result.

The time of exposure required depends upon the light, the sensitiveness of the plate, the object, and the lens aperture, and each one of these factors must enter into the calculation. Some time ago one might happen to meet a photographer of the old school who despised entering into such details as these. If he had an idea of the sensitiveness of the plate, and he was not always very particular even about that, then he would say that the best way to estimate the exposure necessary was just to look at the image on the ground glass and judge from its brightness as to how long should be given. The author once tested an old Daguerreotypist who professed to work in this way by asking him as to what exposure he would advise, and then immediately changing the lens aperture to a definite extent and asking him again. He had no idea of the object of the inquiry, so that his two estimates

were quite genuine and independent of each other. As the only change was in the lens aperture the difference between the two exposures needed was perfectly definite, but the two estimates of the man of experience bore a very different relationship to each other. The fact is, that it is impossible for anyone to estimate the comparative brightness of two images even when they are presented to him the one immediately after the other, much less when there is a considerable interval between the inspection of them. And if it were possible to correctly estimate the brightnesses of the two images, that would not be sufficient, because the exposure necessary is not always proportional to the visual brightness, as we shall shortly see.

But it must not be thought that photographers of the kind mentioned were untruthful or did not give their advice in good faith. They had not the facilities that modern photographers have for estimating the duration of the exposure that is necessary. Thus they had to depend upon their own unaided experience, and this was a much more complex matter than they considered it to be. There can be no doubt that although they thought that their estimates were based upon a simple observation, they unconsciously took many other circumstances into account. It is very difficult to analyse our mental processes. Ask anyone with his eyes shut to touch the tip of his nose with the end of any of his fingers that you may mention and he will probably do it at once and with precision. Now give him a lead pencil or pen stick, he sees the length of it, and ask him to shut his eyes and touch his nose with the end of it. He will probably do it with almost the same degree of precision as with his finger end. But now for the straight stick substitute a curved one such as a clay tobacco pipe. He sees the curve and he sees the length of it, but he will probably fail altogether. It

would be difficult to say what circumstances were taken into account in the first parts of the experiment, but it is certain that the introduction of a new element, the curvature, renders the performance impossible. However expert one may become in estimating exposure by a simple inspection of the image on the ground glass, there always remains the uncertain element of the variable proportion between the visual brightness and the photographic power of the light.

So far as the light is concerned, it is desirable to estimate its photographic power irrespective of the object. It is not the light that comes from the object to the plate that is to be measured, but the light that falls upon the object. If the exposure were to be regulated by the intensity of the light coming from the object, then a dark oak carving and a white plaster model of it would give very similar results, because the darkness of the oak would be compensated for by the proportionally increased exposure. This obviously would be incorrect, for we want the dark object to appear dark, and the white object white in the photograph, and not both to appear as if there was no difference between them.

It is possible to estimate the general intensity of the light by remembering that the best light at noon in mid-winter has about one-fifth the value of the best light at noon in mid-summer, and tables are available to show in what proportion the light falls off for each hour of the day. But the clouds interfere to a very conspicuous degree with the light intensity. There is a certain measure of darkness that would cause anyone to give up all idea of photographing—such fogs, for example, that make it necessary to resort to artificial illumination as if it were night. But considering only those degrees of light that would not obviously stop work by daylight, we may make five divisions, and double the exposure

up to five times according to whether the sun is obscured, the sky is cloudy, dull, or very dull. When working by this method the character of the object is of vital importance, for by simply going into a shady place, as in a wood, the exposure as compared with that necessary in the open may need to be a hundred times as long, without going to an absurd extreme. Tables have been drawn up giving the exposures needed founded on these circumstances, and sometimes these tables have been put into the form of a slide rule or of revolving cylinders. Whatever form they assume the principle of their construction is the same, though the slide rule or the revolving cylinders may be a little more convenient or compact. Such a system of estimating the required exposure is better than no system at all.

The best way to estimate the light is to measure it, not visually but photographically. Ordinary white light, as we have already seen, is not a simple single movement, but is a regularly graduated series of movements, and it is only a comparatively small part of these that affect the eye so as to cause the sensation of light. It is another part of them that is of general photographic efficiency, and, speaking generally, all different things that are affected by light are changed by more or less different constituents of the mixture of radiations that we commonly speak of as light. The actinic power of light, at least in a practical sense, does not depend merely upon the brilliancy of the light to the eyes, as used in earlier times to be taken for granted. Therefore the only way to exactly measure the comparative power of lights to affect any given substance, is to use that substance itself in making the test. For gelatino-bromide plates, the same kind of plate must be subjected to the same treatment as to development in making the test as the plates will be for the actual exposures on the objects to be photographed. But such a method of testing the

light would be tedious and often impracticable, and as there is always a certain amount of variation permissible in the duration of the exposure, this only exact method may be advantageously replaced by a rapid and practicable method that is almost always good enough. Paper is coated with a bromide of silver emulsion and so treated or "sensitised" that when exposed to light it rapidly darkens without any need for development. Thus the same compound, silver bromide, is used as in the actual plates, but its treatment is varied in order to make it a more practical test. This is a very much superior method to any process of estimating brightness by the eye.

The modern actinometer has a piece of such sensitive paper under a screen with a small hole in it, and when exposed to the light to be tested, the unprotected portion of the paper darkens, and when its darkness matches that of a painted tint by the side of the hole in the screen the test is complete. For each test a fresh surface of the sensitive paper is drawn under the opening, or the screen is rotated so as to expose a fresh portion. The exposure necessary is directly proportional to the time required for the paper to darken to the standard tint. If the paper takes twice as long to darken as it did on a previous occasion, then, under exactly similar circumstances otherwise, the exposure of the plate must be twice as long as on the first occasion. Most of the actinometers have movable scales attached to the cases to facilitate the calculation of the required exposure for plates of different sensitiveness and with various lens apertures, and then the apparatus is called an "exposure meter." On a fine summer's day out-of-doors in the shade the time taken for the paper to darken will be from two to four seconds, so that the test of the light is rapidly made. For indoors, when the test might be tedious, a lighter comparison tint is used to save time.

The effect of the aperture of the lens on the exposure we need not trouble further about, because it is clear that the larger the opening the more light is admitted and therefore the shorter the exposure required. The lens diaphragms are marked in such a manner that the next larger or smaller, doubles or halves the area of the aperture and therefore needs a half or double duration of the exposure.

It might be supposed that theoretically the character of the object to be photographed should not be taken into account in determining what the duration of the exposure shall be, because we want a dark object to produce but little effect on the plate that it may appear dark in the print, while a light or white object should produce an increased effect corresponding to its brightness that it may appear to be white. This is true in principle when light and dark objects are present together in the view or collection of things that is to be photographed, and indeed it is obvious that it would be impossible to adjust the exposure to the various parts of the object even if it were desired to do so. Sometimes this is attempted in a crude way by, for example, shading the upper part of the lens so that the light that represents the sky in the picture may be reduced. But such procedure is always uncertain in its results and rarely satisfactory. When, however, we are dealing with an object that is altogether dark or altogether light, it is practically advantageous to adjust the exposure a little, giving say twice the indicated exposure in the first case and half in the second. This has the effect of making the detail a little more conspicuous in the photograph, and actually makes the representation more true to the appearance of the object, because when we look at an object that is altogether dark, our eyes naturally adjust themselves to the darkness by the expansion of the iris, and the dark object does not appear quite so dark as it would if it were surrounded with or intermingled with light objects.

Exactly the same consideration applies to light objects but in a reverse sense. So in making this little allowance we are only doing what our eyes do automatically, and the result is more truthful because of it. These considerations apply to dark tapestry, dark pictures, bronze statues, wooden objects darkened by age, as oak screens, doors, &c., on the one hand, and such things as marble statues, buildings of light stone or with very light walls as sometimes in churches, pictures that are essentially light, drawings or prints done in black lines on white paper, on the other hand. An open landscape with no dark objects or shadows, and the open sea, being subjected to the full glare of light from the sky, need a reduction to about a fourth, while the sky itself may be given an exposure of about one-eighth of what would be given for an average object, when the value found for the light intensity is the same.

If you will paint upon a piece of cardboard the blackest coating that you can of the blackest paint or ink, and take also a piece of the whitest card or paper that you can get, you will then have represented the blackest black and the whitest white available for the usual means of pictorial representation, whether photographic or otherwise. In the dark neither of the cards will be visible because then everything will be black, and black and white are only distinguishable by reason of the light that shines upon them. Put a lighted candle at a distance of say two feet from the two cards and the difference between the black and the white is clearly shown. But if you could arrange so that forty or fifty candles were to shine upon the black card at exactly the same distance that the single candle illuminates the white card, the black card would appear whiter than the white card, and if the number of candles was reduced to about thirty, then the two cards would appear of equal blackness or whiteness, whichever you may prefer to call it. An absolutely white card would reflect

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A FOOT RACE

The estimated exposure given in taking this photograph is the one eight-hundredth part of a second. The maximum speed of each foot in the middle of each step is very much greater than the rate of movement of the man's body, while each foot is stationary at the moment that it touches the ground. There seems to be only one of the twelve feet of the racing men that is moving at about its maximum rate.

all the light that falls upon it and an absolutely black card would reflect none of it, but absolute blackness and whiteness are impossible, for the whitest card does not reflect all the light and the blackest reflects some. We may truthfully say that the only difference between practical blacks and whites is that the blacks reflect less of the light that falls upon them than the whites. As it is found that when about thirty times as much light illuminates the black card as illuminates the white card they are equally bright, it follows that the only difference between the black and the white is that the former reflects about one-thirtieth as much light as the other when they are equally illuminated, as they would be under ordinary conditions. This range of one to thirty is thus about the maximum available; but if the paper used is not of the whitest and the blacks are not of the deepest, the difference possible is at once reduced. And if the paper is tinted or toned, the possible range of depth may be as little as about one to ten or even less.

With such a restricted power at command it is impossible to represent without compromise the great range of brightness that is met with in nature. If the fine modelling of the bright clouds is well shown, so much of the possible range of brightness in the picture is taken up by it that there is an unduly small remainder for the landscape and this therefore appears oppressively dark. If the dark parts of the subject are made the best of, then the brighter parts suffer. This therefore is a full justification for the adjustment of the exposure to suit the subject, when that is possible, within the comparatively narrow limits suggested above.

This restriction of the photographer with regard to the extremes of black and white at his disposal, leads some, whose only aim is to make pleasing pictures, to invariably select subjects that present very little contrast, and that can therefore be satisfactorily rendered by the range of

brightness available for the print. They prefer grey days, evening scenes, photographing sometimes even after sunset when all deep shadows and high lights have given place to a general dim illumination. From a merely technical point of view such subjects are more easy to represent satisfactorily than those that show more brilliant contrasts. It is easier to get the values, or different degrees of brightness, correctly represented because there is so small a range of them. Although it is waste of time to attempt the impossible, it is not desirable to confine our endeavours to what is easy, merely because it is easy.

CHAPTER IX

THE DEVELOPMENT OF THE PLATE

THE use of the negative is to furnish a print by putting a piece of sensitive paper beneath it and then exposing it to light. The negative shields the paper where the light is not required to act, and it must therefore have a substantial degree of opacity. The simple exposure of the plate in the camera, as described in the last chapter, produces no visible effect upon it, and if after the exposure the sensitive silver bromide were to be dissolved away, there would be nothing to be seen on the glass except the transparent film of gelatine. Exposure alone under these circumstances cannot give a negative, all that it does is to render the silver salt less stable and so give the possibility of making a negative by taking advantage of this instability. It would be quite possible under different conditions to cause the light to do the whole of the work, and this was the only method known until, nearly eighty years ago, the production of an invisible, or "latent" or "developable" image was discovered. When the light acting on the plate is only required to initiate or render possible the required change, the time necessary for the exposure in the camera is enormously reduced.

The word development has a general meaning as well as its technical meaning when used in connection with photography; and even when it is limited to our subject it has various meanings which must not be confused. Niépce developed his bitumen photographs a hundred years ago. A film of bitumen similar to a coating of

varnish covered the surface of metal or other material, and was exposed to light in a camera, until by the action of the light those parts of the film that it acted on were rendered less easily soluble in an oily liquid. This image was practically invisible and was "developed" by applying the solvent carefully so that it should remove the more soluble parts of the film without interfering with the exposed and less soluble parts. Here the whole of the change was effected by the light, and the development was simply the removal of the unchanged parts. We shall find other examples of this kind of development in the consideration of printing processes.

Daguerreotypes were developed, but on quite a different principle. The effect of the light here also was invisible, and the image was developed or made visible by subjecting it to the action of mercury vapour. The metal condensed in minute drops more readily on those parts of the plate where the light had acted than on the other parts. Wet collodion plates were developed in a similar way, only instead of the deposition of metallic mercury from its vapour, metallic silver was deposited from its solution. This kind of development can be very easily illustrated by breathing upon any ordinary piece of glass. If the glass is quite clean an even deposit of drops of moisture from the breath will be formed, but if the glass is not clean, the deposit will be irregular and uneven. The irregularities will often be more conspicuous as the deposited moisture evaporates, the moisture remaining the longest where it was most copiously deposited. It is very usual to test for invisible impurities on the surface of glass by breathing on it, and in this operation these invisible deposits are developed into visibility by the deposition of the little drops of water upon them at a different rate or in differently sized drops from its deposition upon the clean surface. There is nothing essentially photographic in development by dissolving away or in development by deposition, they

are quite common operations used by multitudes of persons who never give a careful thought to the matter. They have doubtless been in use for thousands of years.

But the kind of development that we are about to consider is of an essentially different character. It is possible to apply certain theories as to the course of the changes that take place, and so to compare this development with development by deposition, but this is not a suitable opportunity to endeavour to apply theories that may or may not stand the criticism of further investigation. The difference in the nature of this kind of development has always been recognised, and it is called "chemical" to distinguish it from development by deposition, which is called "physical." Clearly in the latter case there is no chemical change involved in the actual process of development in any of the substances concerned; the water remains water, the mercury remains mercury, and the silver remains silver; they are merely discriminatingly deposited.

In the development of an ordinary negative, the silver bromide that has been rendered unstable by the action of light is decomposed, its bromine is taken away from it and the metallic silver remains. This is exactly the effect that the light itself would have if its action were allowed to continue under suitable conditions. But it is not true to say that the light starts the change and the developer continues it, because in that case the exposure and the development should be interchangeable, more or less exposure with less or more development should lead to the same result. We have seen very clearly in the previous chapter that the facts are very far from this, and that increasing the exposure beyond a certain small limit, so far from facilitating development, hinders it and may render it impossible. The opening of a door will make the entrance of an audience possible, but it will never fill the building. The opening of two doors will further

facilitate entrance, but if the people do not go in the place will remain empty. So the exposure makes development possible, but it is not a stage in the actual production of the image. It is the developer that does this, and the light action simply determines where it shall act. In the terms of the illustration, it opens the door to this apartment but not to that, it opens this door wide that many may enter and the other to a small extent so that only a few can get in there.

The first requisite of a developer is that it shall be able to remove bromine from silver bromide, and the second is that it shall not be able to do so unaided, but only when its action has been facilitated by the previous action of light or its equivalent. Whatever is the prime reagent employed, it is desirable to be able to adapt it to varying circumstances by accelerating its action or retarding it, and that it may be caused to do its work in a steady and well-balanced manner. The mixture used for developing therefore consists generally of the developing agent proper, an accelerator, and a retarder. But why, it may be asked, must there be two agents so apparently opposed to each other as these last? Could not the accelerator be reduced in its quantity and the retarder dispensed with? This may be possible but it is hardly ever desirable. As a rough illustration, we may regard the developing agent itself as the wind that carries the ship along, the accelerator as the sails that enable the wind to act more powerfully on the ship, and the retarder as the ballast. The greater the weight of ballast the more sail will be required to maintain the same speed, but the reduction of both cannot be carried beyond a certain point without instability and uncertainty as to the progress of the vessel. The fly-wheel attached to a steam-engine retards its movements, but it is desirable in order to overcome the irregularities of the movements that would be produced by the engine without it. In an analogous way

the retarder is needed to steady the reaction while the accelerator urges it on.

There is one other constituent that is necessary to form a well-balanced developing solution. The developing agent, as it takes the bromine from the silver bromide of course combines with it, and the product of this combination almost always has a deep colour. This if uncontrolled would stain the negative. The final constituent of the developer is added to prevent this and keep the negative clean. We will now pass in review each of these four constituents.

First with regard to the developing agent itself. We have already referred to the fact that Wedgwood and Davy at the beginning of the last century found that leather was better than paper for this purpose because it rendered the silver salt deposited upon it more sensitive. The Rev. J. B. Reade, working on similar lines and having no more white leather, attempted, as he said, to "tan paper," that is to prepare paper in the same way that leather is prepared in order to confer upon the paper the accelerating influence found in the leather. He applied to the paper an infusion of gallnuts, these being one of the common sources of tannin used in the preparation of leather. Fox Talbot heard of Reade's procedure, and discovered that the tannin or gallic acid might be applied after the exposure, or a part of it might be so applied, in order to bring out or develop the image that was not visible before its application. Tannin may be regarded as a compound of gallic acid and glucose, and the acid is easily obtained from it. When gallic acid is heated to a moderate temperature it gives a sublimate of light feathery crystals, which at first were thought to be merely purified gallic acid but were afterwards found to be a different substance, what we now call pyrogallic acid or pyrogallol. It was in this accidental way that pyrogallic acid came to be used

as a developer, and it is strange that even to the present day it is largely employed, for nothing superior to it in every way has yet been found. Later on one or two other substances were found serviceable as developers, but it was not until about twenty years ago that it was sought to discover the particular characteristics of developers from a chemical point of view, in order that the chemist might have a definite idea as to the general nature of other substances that might take the place of the pyrogallol. Clearly there was no obvious reason why pyrogallic and gallic acids should stand alone with regard to this power of development, and it might happen that other reagents would be superior to them. Doubtless also there was the commercial incentive, that a better developer would be profitable to the maker of it.

All definite substances have what chemists call a constitution, that is their constituent parts can be so represented that the relationship that they bear to each other will indicate the possibilities of change of that particular substance. There are often found to exist several substances of exactly the same composition, the same elements in exactly the same proportions, but with different and sometimes very widely different properties. The difference in such cases must be due to the relationship that the various parts of the compound bear to each other, and by ascertaining the ways in which it is possible to change such compounds, the relationship of the various parts to each other may be discovered and definitely expressed. By investigations on such lines, the chemical characteristics of developers as a class were worked out, and as a result a great many efficient developers were placed at the disposal of the photographer. Each of these has its own characteristics, but their differences are not remarkably great, and for practical purposes it is hardly worth while to do more

than to divide them into two classes, namely, the "slow" and the "rapid" developers. The words slow and rapid do not refer to the whole process of development, but only to the first visible effect of the developer. When a properly compounded slow developer is put upon a plate, the high lights of the image appear first, then the middle tones, and finally the detail in the shadows; but with a rapid developer, the whole image appears to begin to come at the same time and very much more quickly after the application of the solution than in the other case. But this distinction is not always very conspicuous, and the most rapid of the "rapid" developers may be made to act like a slow developer by suitable means.

The accelerator is an alkali, because the developing agents are more ready to take up bromine or other similar substances in the presence of an alkali. Those who do any practical photographic work might try the experiment of shaking up in a tube a little pyrogallic acid in water. There will be but little change. If now any alkali, such as some washing soda or ammonia, is added and it is shaken again, the solution will rapidly darken, and this production of colour shows that oxygen from the air has been absorbed and combined with by the pyrogallic acid. In an analogous way, if a pyrogallic acid developer without any alkali is put upon an exposed plate it will act very slowly indeed, requiring perhaps a whole day or more to effect development, and in order to make it produce a respectable image it will be desirable to give the plate a longer exposure in the first instance.

An accelerator may not always be an obvious alkali. Acetone or formic aldehyde, for example, are not alkalies, but when added to a developer they seem to act as accelerators. The fact is that they act only indirectly. Compounds of the type to which these belong will combine with acid sodium sulphite. Now the sodium

sulphite that is put in the developer may be regarded as a compound of acid sodium sulphite and caustic soda; it can be divided into these two substances, but so long as they are together they neutralise each other. When, however, acetone is added which can combine with the acid sodium sulphite, the caustic soda becomes available for the purposes of the developer. Trisodium phosphate is sometimes used as an accelerator. This may be regarded as a compound of disodium phosphate and caustic soda, and when dissolved in water the caustic soda is at once available. Therefore the use of these substances is only an indirect way of adding an alkali, and though there may sometimes be an advantage in employing them, it is generally more satisfactory to add a simple alkali directly. Moreover acetone and formic aldehyde are volatile and pungent substances that are disagreeable to have to deal with, and if inhaled in quantity are likely to do injury to the individual. There are a few developers that will work fairly satisfactorily without any alkali to accelerate them, but these generally contain in themselves rather more of an alkaline character than the others.

The retarder is almost always potassium bromide. A few other substances have been suggested, but they do not meet with general approval. We have likened the retarder to the ballast of a sailing-vessel. There are some vessels that need no ballast, and there are some plates that need no retarder. This is so especially with slow plates, the gelatine of the film is a sufficient retarder. But there are other cases where the photographer may be deceived. Just as in building a vessel the keel may sometimes be made heavy enough to steady it without the addition of ballast—the ballast, so to speak, being part and parcel of the vessel—so the plate maker can put a little potassium bromide into his emulsion, and the desirable retarder then becomes a part of the plate, and obviously need not be added to the developer.

The final constituent of the developer is the stain preventer, which is generally sodium sulphite. If the experiment suggested above of shaking up a solution of pyrogallic acid with an alkali be repeated, but with the addition of sodium sulphite, the effect of the sulphite in preventing the production of the colour will be demonstrated, although the absorption of oxygen from the air will take place pretty much as when without the sulphite the solution became very much darkened. The use of sodium sulphite for this purpose was suggested very soon after gelatine plates began to be generally employed, and until then the negatives made were badly coloured with the staining matter produced, for it is not simply the bromine from the silver bromide but also the oxygen of the air that comes into contact with the surface of the developer, that is taken up by it and converts it, in the absence of sulphite, into darkly coloured substances.

After so much preliminary consideration of the various constituents of the developer, we must endeavour to follow the course of its action upon a properly exposed plate. We have already indicated the differences that will be caused by too little or too much exposure. If the developer is pyrogallic acid and a sufficiency of sodium sulphite has been added to prevent the production of coloured substances, and if the accelerator has been rather sparingly added so that the total time of development is about fifteen minutes, the plate when placed in the developer will remain for two and a half to three minutes with its creamy white surface unaffected. Then a slight darkening will be apparent at those parts where the most brilliant parts of the image fell, and the darkening will very slowly increase. As it does so those parts where the image was rather less bright will begin to appear, and as these are all gradually growing in density, the detail in the darkest parts of the image will come out. Now the various parts of the image that first appeared will be

invisible on the surface of the plate, "buried" as it is said, because the action on the surface will be equal over all those parts of the plate, but by holding it up to the light and looking through it, it will be seen that the gradation of the whole image has been duly preserved. It only remains now to dissolve away the silver bromide that has not been utilised to form the image by allowing the plate to remain in a solution of sodium hyposulphite until the white creamy appearance of the film has gone and the black image stands out clearly in a transparent and colourless medium. After a thorough washing to remove all the soluble matter from the film, the plate is put to dry.

If the subject photographed was of such a character that the image had not too great a difference in brightness between its brightest and its darkest parts, or if the plate used was one that would not give too much contrast with such a subject, then the development presents no difficulties, because it is only necessary to let it go on until all the bromide of silver that was made developable by the exposure has had its bromine removed from it. If the developer were well balanced and the plate of good quality, the plate might remain in the developer for twice as long as necessary without harm, for when the development was complete there would be no further change possible within a reasonable time. But if it were possible to produce too great a contrast in the negative by reason of the character of either the subject or the plate, then a certain measure of skill is necessary to know when the development has been carried far enough. If the photographer is dealing with subjects of very various characters and wishes to render each of them as perfectly as possible, then whatever rules he may find useful he must depend finally upon his discretion, because the density of a negative cannot be measured as it is being developed.

There are rules concerning development that are sometimes a guide as to when the operation has been carried on long enough, that is as to when a sufficient degree of contrast has been obtained. Mr. Alfred Watkins has found that the time required for the first effect to be visible bears a definite proportion to the total time of development under certain circumstances. By noticing how long the developer takes to produce the first visible result, this period can be multiplied by the known factor and development carried on as long as indicated. With ordinary developers this multiplying factor varies from about four to forty, not that the total time of development varies to anything like this extent, but that some developers produce a visible effect so very soon after they are poured on the plate, while others may be more than ten times as long in this first stage. Another method consists in finding how long a specific developing solution requires to develop a given plate exposed on an average subject and how much this time is affected by a change of temperature, for the higher the temperature the quicker the action, as is the rule in cases of chemical change. It is obvious that there is no law involved in either method, they are only rules that apply in average cases. If, however, either of these methods is implicitly followed, the probability is that the average photographer will secure a greater proportion of good negatives than if he trusted solely to his discretion. Those who have had comparatively little experience are so liable to be misled by their own ideas, that slavishly following an average rule is less likely to lead to misfortune. There is also another consideration, namely, that the greater number of photographers work in grooves, their work is all of very much the same sort. The professional portraitist has his style, the amateur generally settles down to more or less of one class of subject, and often, too, only photographs in very nearly the same sort of weather. Then the uniform

method of development is still more likely to yield the best average of results.

The total time required for development can be varied within very wide limits, from two or three minutes up to some hours, for example, according as the developer is diluted, restrained, or contains little accelator. When many negatives have to be developed, it is possible that the total time required may be shortened by prolonging the time necessary for each plate, because by so doing the manipulation may be facilitated. This fact has led to the introduction of various tanks and similar devices, in which a considerable number of plates or films are placed in racks or suitable supports and allowed to remain there in a diluted developer for the requisite time. The Kodak Company, in 1903, issued a developing machine for their roll films in which the whole strip of flexible film, after exposure, was wound off its roller on to a spindle so that it lay against an apron with ridges at its sides to keep its convolutions apart, and was then slowly turned round in the dilute developer for the requisite time. Instead of this continuous rotation, the coiled film is now put into a cylindrical vessel with a tight lid, and this is turned over two or three times during the necessary period. This tank method of development is often so arranged that the greater part if not all of the operation may be carried out in daylight without risk of accidental exposure of the plates or films.

Whatever the method of work, the aim of the photographer should be to get the image of his negative to consist of pure silver, and the gelatine in which the particles lie should be clean. To secure this the fixing must be complete, that is the sodium hyposulphite must be allowed ample time to dissolve out the bromide of silver that has not been utilised in the production of the image, and the subsequent washing must be prolonged that all the chemical substances in the gelatine from the

E. O. Hoppé.

MAETERLINCK

An example of Modern Portraiture.

developer and the fixing bath may be thoroughly removed. It is easy to talk of thoroughly washing a gelatine plate. By soaking it in fresh portions of water repeatedly, a proportion of the soluble matter is removed each time, but never more than a portion, so that an absolute clearing out of the soluble matter is not possible. But such an action is rarely if ever so simple as it might be thought to be. The gelatine and the silver image itself tend to retain small quantities of materials with which they are in contact, perhaps in something like the same way that a fabric retains the dye with which it is coloured. It has been stated that the silver image holds to itself a little of the bromide of silver that one wishes to remove in fixing the plate, and that this bromide of silver cannot be got away. This statement needs confirmation; but if true, the bromide of silver retained must be a very small amount when the negative is properly made.

But there is another interfering substance that is often present because of insufficient care on the part of the photographer. We have seen that the developer when acting takes bromine from the exposed bromide of silver, and that the bromine when it combines with the developer converts it into coloured substances, to avoid which the sodium sulphite is added. Some people seem to be afraid of sodium sulphite, and in many formulæ that are recommended it is put down in insufficient quantity to do the work that is required of it. In such cases colouring matter is produced, and as the bromine leaves the silver and goes to the developer and forms this colouring matter, it is produced exactly where the silver image is produced and is roughly proportional to it. There is thus a compound image of metallic silver and colouring matter from the developer, and that this is so can be easily proved by dissolving away the metallic silver, when the image in this colouring matter remains and is clearly visible. This colouring matter is undesirable for many reasons which

cannot be fully explained here. The negative in which it exists cannot be depended on in any way. It may sometimes be advantageous for non-critical work, when because of the plate being poorly coated, or the subject very wanting in contrast, or the treatment of it defective, there is too little silver to furnish a suitably dense image. But if the silver image is too thin and it is clean, there are methods of working with it or increasing its density that are not subject to any of the disadvantages of the presence of the stain image. To avoid the production of staining matter, it is desirable to use sufficient sulphite in the developing and to add a little sulphite and alkali to the fixing solution of sodium hyposulphite. If then a little staining matter has been formed, the alkaline solution tends to keep it in a soluble condition and to permit of its removal by washing.

When the developing solution darkens because of undue exposure, for the air will act on it in a similar manner to the bromine that it takes from the silver bromide, or because of insufficient sulphite, the gelatine also is generally stained of a more or less uniform tint. Such a stain retards the passage of light through it, and hence is detrimental in the printing process. The old empirical method of attempting to cure such a plate was by the application to it of an acid liquid, and many such "clearing baths" were recommended in the early days of gelatine plates, and a few have survived even to the present. In general, the effect of the acid is not to remove the staining material, but to change its colour to a lighter tint which of course is less obvious—brown to yellow, for example. At the same time, it tends to make the colouring matter insoluble, and so may do more harm than good. The proper method of treating a developer stain is to wash it away by the repeated application of water to which

a little alkali (preferably caustic soda) has been added. The alkali keeps it soluble and visible, and when all that can be removed in this way has been washed away, the small residue of stain will probably be so slight as to be invisible, and if in greater quantity will not be lightened in colour by any so-called "clearing solution."

CHAPTER X

FINISHING THE NEGATIVE

It is an entirely mistaken though very general idea that when a plate has been exposed, developed, fixed, washed, and dried, the negative ought to be perfect, and that if it is not, it is either the fault or the misfortune of the photographer. It is also a mistaken and common idea that it is possible to define a perfect negative in definite terms which express certain relationships between it and the object photographed or between the print that it will yield and the object, and that therefore there is only one kind of negative that is perfect for any given object under definite conditions.

A perfect negative is neither more nor less than one that will do exactly what the photographer wants it to do, and the skill of the photographer is shown in his ability to produce exactly what he desires. Probably there is not one negative in a thousand or in many thousands of those that are made that is other than just what happens to come as the result of a prescribed routine. A person whose work is of this kind only, is no more entitled to be called a photographer than one is entitled to be called a geometrician because he can neatly draw geometrical figures. A skilful worker must at least have control over his tools; but this alone is not sufficient, for a machine might have a far more perfect control than he by a life of practice could ever hope to attain. He must know in what direction to exercise the control, and it is in this that he becomes superior to the machine and rises from the

position of a mechanic to that of an artisan or artist. A large proportion of the photographs that are produced are merely machine made, and poor at that, because the machine is a human machine with all its wonderful adaptability uncontrolled. A photographer, to be worthy of the name, must be able to form a definite idea as to what he wants, and then be able to work straight towards the realisation of his idea. To this there is no exception, for it applies equally to the getting of a record of the movements of an instrument, to the photography of a spectrum, and to the production of photographs which are generally distinguished as "pictorial." By control in this connection we mean the power to apply and utilise for definite ends photographic instruments and methods, and not the ability to mix with the photography the methods of other arts. It is necessary to add this explanation, because the word "control" is so often used in connection with photography in this latter sense, and too often the "control" does badly what photography would have done well. Such productions, of course, are not photographs.

We sometimes hear it said of a negative that it is fine or perfect, but that it will not give a good print. One might just as well say of a watch that it is perfect, but that it will not keep good time. But look at it, they will say, there is not a spot upon it, it is brilliant, full of detail, clean, and altogether technically perfect. If now you will ask the same individual to buy a watch because the case is brilliant, full of wheels, with not even a speck of dust to be seen, and "technically perfect," he will think that either you are a fool or consider him to be one. Now a watch has only one duty to perform, namely, to keep good time over a sufficiently long period, and time is the same to all persons. But a negative may be good to one person because it serves his purpose, and useless to another because his aim is different. The skilful photographer

should be able to produce any kind of negative from any subject within the range of the possibilities that photography allows. For this purpose the negative made as already described has often to be subjected to other treatment.

The negative consists of particles of silver distributed through the gelatine film in such a manner that they represent the form of the object as depicted by the lens, and by their density, the variations in the brightness or whiteness of its different parts. These particles cannot be moved from one place to another in the film; therefore at this stage there remains no power to alter the "drawing" of the picture; that is settled once for all when the exposure is made. It is only in the density of the various parts that change is possible, and this is effected by adding to the silver to increase its density, or by dissolving some of the silver away in order to reduce it. The first process is called "intensification" and the second "reduction." If a negative is so thin in its densest parts that the light is very little diminished by it, and consequently the print shows very little difference between the darkness of one part and another—the print, that is, is flat and dull—then it is desirable to increase the density of the negative. On the other hand, the negative may have such excessive contrast that the more transparent parts will give a good result on the print before the light has sufficiently penetrated the darker parts, so that a print at this stage of exposure would show patches of white without detail or gradation; and if the exposure is continued until the darker parts of the negative give a suitable result on the print, the effect under the thinner parts will be buried in blackness. In this case it may be desirable to "reduce" the negative. The need for the reduction of the negative is generally, indeed one might say always, due to an error of either exposure or development, and when intensification is necessary it may be also due to error in the previous

work, though often it is otherwise. The subject may present such uniformity of brightness that its image will not give sufficient contrast, and in experimental and scientific work it may be desirable to increase the maximum contrast that can be obtained by development.

In order to understand the effect of these processes, it must be borne in mind that in a normally exposed and developed negative the bulk of the particles of silver that represent the detail of the thinner parts of it—that is, the shadows and darker parts of the object—lie nearer to the surface of the gelatine film, and that as the deposit increases, the particles extend deeper down in the film. In the treatment of a gelatine plate every action begins at the outer surface of the film, and therefore its effects show there first, and passes deeper into the film as the action is continued. If therefore by any means the outer surface of the film is removed as if it were scraped off, there will be carried away a larger proportion of the deposit of silver particles where there is least deposit than where the deposit is thicker. The thinner parts may be made so thin that they are almost obliterated, while the denser parts lose only a small proportion of their substance by such a process. Thus the action is not proportional in the various parts of the plate and the character of the gradation is altered. The difficulty with regard to this alteration is that it is uncertain and irregular, and it is impossible to tell from the resulting image what the original negative was, or from the original what it will be if subjected to such treatment. A method that cannot be depended upon is obviously one to be avoided, for in all sound workmanship it is not the possibility of success with a hope for a lucky result that is sought after, but the certainty of success.

There is one case where such a method of reduction is safe and good. In the photography of a subject that is only black and white—that is, free from shadows or half

tones, like a pen-and-ink drawing on white cardboard—it is desirable to get a good deposit on development to represent the white board, and none where the image of the black lines falls. But if the blackness is not as intense as it might be, or if the exposure has been a little too long, there may result a slight deposit where none was desired, and this deposit may be cleared away by reduction. Something will be lost from the denser parts of the negative, but probably not very much, and as the cardboard is equally white all over the negative is equally dense, except where the lines are, and there is no gradation to falsify.

Exactly the same considerations apply when, instead of rubbing away the surface of the gelatine, a liquid is applied to the negative that will dissolve the silver out from it. This begins to act at the surface, and therefore dissolves away a larger proportion of the thinner deposits that lie chiefly near the surface than of the denser deposits that penetrate more deeply into the film. The unproportional character of the action will be increased if the solvent acts very quickly in proportion to the time that it requires to penetrate the film; and conversely, if it were possible to get a solvent that was slow in action but quick to pass in and out of the film, so that every particle of silver was always surrounded by the solvent in the same condition, then every particle would be subjected to the same action and the reduction would be proportional throughout. It is possible to approximate somewhat to this condition, and some reducing reagents have been stated to give a proportional effect, but such a result can never be certainly obtained.

There are a great many substances that may be used to make the image on the negative thinner. The surface of the dry gelatine may be rubbed away by means of a rag moistened with alcohol, or "globe polish" may be used, or the surface of the gelatine may be softened and

made slimy by the application of an alkali or acid, and then wiped off. To dissolve the silver it may be first converted as far as necessary into chloride of silver by means of a solution of ferric chloride, and the chloride of silver may be dissolved in a solution of sodium hyposulphite—the ordinary fixing bath. The ferric chloride and sodium hyposulphite cannot be mixed in order to dissolve the silver immediately it is changed into the soluble compound, because they would act on each other and become inactive, but this result may be obtained by using ferric oxalate or potassium ferricyanide instead of ferric chloride. The silver is then changed into silver oxalate in the first case and into silver ferrocyanide or ferricyanide in the second case, and these compounds dissolve immediately they are formed, being in the presence of the sodium hyposulphite. Ammonium persulphate is often used as a reducer, and it is usually thought to act either proportionally throughout, or else to a greater extent on the denser deposits than on the thinner deposits. But as it is not known how it acts, and as the nature of the material that is left to form the image has not been determined, it is not advisable to apply it to any negative of value. There are many other substances that can be used to dissolve away some of the silver without injuriously affecting the gelatine.

It is desirable to avoid the reduction of negatives, not because it is an added operation, but because the result is always uncertain. It is uncertain because it is partial (if the action were made complete, there would be no image left), and because it is partial it is unproportional and variable. Circumstances are very different in the case of intensification. Here the action can be made complete because it is possible to ensure that every particle of silver is acted on in exactly the same way, and being complete the result can be made strictly proportional and definite. Knowing exactly what and

how much of it has been added to each particle of silver, it is possible to discover, if we should wish to do so, what the negative was before the treatment, or to know exactly what any negative will become by the treatment. It must not be thought that every method of intensification is of this desirable character. Many of those who have worked at photographic problems have had no sound principles to guide them, and they have judged of the results that they obtained merely by the appearance. If a negative was thin and the application of anything made the image appear denser without destroying the gelatine or causing spots or stains, the substance used was recommended as a good intensifier, even in the total absence of any knowledge as to how it acted to produce the result or of what substance the final image consisted. The inevitable result of this was that negatives as intensified had images consisting of all sorts of things and mixtures of things, some volatile, some soluble, some coloured, and many unstable. And it naturally follows that many valuable negatives have become useless from changes in them that might have been foreseen if any one had properly examined the process before it was applied to practical work.

For general purposes in intensification the material added to the silver particles that constitute the image should be stable, black or grey—that is, not coloured—the process should preferably allow of it being added in definite quantities, and there must not be any tendency for the solution used to dissolve any part of the image. In some special cases the deposit may be coloured without disadvantage, but the very fact that it is coloured shows that it is more opaque to light of some colours than of others, and that it will on that account give different results with various printing methods. A coloured image is always liable to be a disadvantage

because the light that passes through it on account of its colour may prove an annoyance.

Many of the solutions that are recommended for intensification will dissolve a part of the substance or substances that have been added to the original silver, and sometimes even a part of the silver itself, so that there are two opposing actions going on at the same time. While the silver is being added to in the lower strata of the film, this action has been completed at the surface, and the product here is being dissolved away. The net result therefore is uncertain, and it is impossible to get a proportional action.

The most usual method of adding to the silver of the image is to put the plate into a solution of a compound from which the silver will take a constituent which will form an insoluble compound with the silver, while the residue of the reagent is also insoluble. Ferric chloride is a compound of iron and chlorine from which silver can take some of the chlorine to produce insoluble silver chloride. But the compound of iron and chlorine that is left is soluble in water, and therefore is not deposited on the silver. If the ordinary chloride of copper is used, silver chloride is produced as before, and the copper chloride that is left is insoluble in water and does remain where it is produced, in close contact with the silver. That is, it remains to a greater or less extent, for it is so easily changed by the air to compounds that are soluble or partially soluble, that the amount remaining is not definite. Mercuric chloride, sometimes called corrosive sublimate, is also able to give some of its chlorine to silver, and it has the great advantage that the mercurous chloride that is left is quite insoluble and not acted on by the air, so that it remains completely with the silver chloride, the two chlorides combining to form a definite compound which will not change at all, however long the corrosive sub-

limate solution is allowed to remain in contact with it. By looking at the negative that has been treated in this way with a magnifying glass, it will be clearly seen that the original silver particles are notably enlarged, for they have had considerably more than twice their weight of material added to them. But this double chloride of silver and mercury is white, and if the negative at this stage were used for printing, it would be found that in spite of the greatly increased quantity of material that now forms the image, and the consequent smaller spaces between the particles, more light would pass through it than before because the white particles reflect it, or pass it on, so much more freely than the black particles. On this account, for practical purposes the negative is now worse than at first. It is necessary to change the white image into a black one, and for this purpose innumerable reagents have been proposed and many extensively used without any knowledge of the character of the change they brought about or the composition of the black material that they leave to form the image.

There is only one substance that has been proved to effect a definite and simple and advantageous change. Ferrous oxalate merely takes away the chlorine from the white compound of silver, mercury, and chlorine, and leaves the whole of the silver and the whole of the mercury together as a black or greyish black deposit. The ferrous oxalate can do nothing else than effect this simple change however long it may remain on the negative, and there is no circumstance that is likely to interfere with the change or the product. The removal of the chlorine reduces the size of the particles, but all the original silver remains with the addition to it of nearly twice its weight of mercury, and as the mixed metals are of the same colour as the original silver, the image is now more able to resist the passage of light through it than it was at the first. This process of intensification has the advantage

that it may be repeated as often as desired on the same negative, each operation adding a definite proportion of mercury to the image.

Two very favourite reagents for blackening the white image produced by mercuric chloride, are (1) ammonia and (2) potassium cyanide dissolved in water with as much silver cyanide dissolved in it as it will take up. It is not necessary to trace the action of each of these. They both have a solvent action on the product of the first change, and so begin to thin the image as soon as the blackening has taken place. Ammonia dissolves away some of both the metals, and leaves the remainder in the form of black compounds of complex and variable composition. The cyanide solution leaves to form the image a mixture of silver as metal, chloride of silver, cyanide of silver and cyanide of mercury. Such mixtures could not be expected to remain long without change; nor do they. The image that ammonia leaves can generally be found to have altered within a week or two if the density of the plate is suitably measured. These methods are not reliable, although they are so much used. They are of service in technical work, in the production of negatives of simple black and white subjects if the negatives are not required to last longer than for a few months.

There is another method of intensifying negatives that is exactly similar in principle to the mercury method, in which a ferricyanide is used instead of a chloride. The changes that take place are a little more complicated, because instead of the simple substance chlorine we deal with a complex substance that contains iron, carbon, and nitrogen. Any metal that forms a soluble ferricyanide and an insoluble ferrocyanide is available for this method, but uranium and lead are the two chiefly employed. After treatment the image consists of a mixture of the ferrocyanides of the added metal and silver, a great deal of new material being added to the original silver. If uranium

ferricyanide is used, the silver image is converted into a much denser reddish brown image, which has the disadvantage of being coloured and allowing a greater proportion of the red constituent of light than of the green and blue to pass through it. Such a partial action is always undesirable, because various sensitive materials used for printing are affected differently by the different constituents of light, and it is preferable to make negatives that may be used with success for any printing process that may be desired. When lead ferricyanide is used, the resulting image is white, as in the case of the mercury methods, and it is very dense, for the silver gets about three times its weight of lead added to it in addition to all the iron, carbon, and nitrogen, that are necessary to form the ferrocyanides of both metals. The white image is blackened to render it serviceable by changing the two metals into their sulphides, which is easily done, but however treated the image is so very much denser than the original, that the method is rarely suitable for practical purposes.

It is possible to increase the density of the image of a negative that is too thin by adding more silver to it. In the development of a wet collodion plate the visible image is produced by the deposition of silver that is in solution in the developer upon the invisible image that has been produced by light. The silver that is in the solution is just upon the verge of separation from it, and the disturbance caused by the presence of the silver salt in the unstable condition caused by its exposure to light, determines the deposition of the silver in its immediate presence. The metallic silver itself that forms the visible image is also able to cause the deposition of more silver upon it, and if the image has not become dense enough by the time the stability of the developing solution has broken down and it begins to deposit silver without the presence of any extraneous cause, this solution can be

thrown away and a new one applied. And so the density can be piled up to almost any extent. The silver image in a gelatine plate can be added to in a similar manner, but this method of increasing density is not to be preferred. It is more subject to irregularities in gelatine than in collodion, and the photographer is dependent on the appearance of the image for an indication as to when to stop the action.

If we were to consider all the possible methods by which the silver image of a gelatine plate may be strengthened, we should have an almost endless task. But for the sake of showing what great and varied resources are at the disposal of the photographer who understands his subject, it may be mentioned that the use of mercuric iodide gives rise to numerous methods, that platinum may be deposited on the image, though its deposition is accompanied by other changes, and that if a simple solution of pyrogallic acid is put on to the plate and allowed to darken by exposure to the air, the image will be increased in density by the deposition upon it of the coloured products of the decomposition of the pyrogallic acid. A second negative may be made and put on the first, and if this is made on a paper or film support, it may be attached to the back of the other in a permanent way. The back of the negative may be coated with dextrine made sensitive with a bichromate, and then exposed to light through the negative. Where the light acts, the stickiness of the dextrine is diminished by the change that takes place in it, and if then a pigment in powder is lightly brushed over it, it will adhere to those parts where the light has not acted, and produce a kind of second negative on the back of the plate which will reinforce the original image. All these methods have been used and some of them extensively, and some of them may still be of value in certain difficult cases.

The commonest of all methods of altering the negative

so that it will give the kind of print that is desired, so far as professional portraitists are concerned, goes by the name of "retouching." The film is coated with a varnish, put on by gentle friction, that gives a finely matte surface, so that marks may be made upon it with a lead pencil. The retoucher then strengthens those parts that need it by shading them with the pencil in a suitable manner, but on an entirely different principle from the methods described above. He does not seek to maintain the character of the negative, but rather to alter it. His business is to make up for the shortcomings of the photographer, and, as a rule, also to alter the negative so that the prints may be more acceptable to the purchaser. Freckles, spots, and wrinkles that are too pronounced are modified or obliterated, and if the sitter thinks that in the photograph her cheek is too round or her waist too large, or that any feature is not shown at its best, it is the retoucher's duty to remedy these details. If a part of the negative is too dense, so that it gives too light an effect in the print, he will scrape or pare away the film. And by such methods he will alter the negative in any desired way to please his customer.

Retouching, of course, is not photography, and a portrait that has been produced by this combination of processes is called a photograph by courtesy rather than in fact. A few of the most notable portrait photographers do not retouch their portraits, and their productions are real photographs. From a business point of view there is nothing to be said against retouching, but a retouched portrait loses much if not all of its value as evidence of the character of the person represented.

In scientific work of all kinds, retouching should be strictly avoided. The chief value of a photograph is that it is an impersonal record, whether of a person, or an animal, or a building, or of the course of a scientific experiment. Any handwork on either the negative or the print renders

the photograph unreliable. The manipulator himself *may* know exactly to what extent he has modified it, but even he can hardly be sure that his handwork has not extended to some little detail that may eventually prove to be of vital consequence, though at first it seemed to be quite unimportant.

CHAPTER XI

PRINTING IN SILVER

THE chief difference between a photographic print and a negative is the reversal of the lights and shades, the opaque or dark part of the one corresponding to the transparent or light part of the other. In the very early days of photography this was the only distinction, and even at the present time what are generally understood as printing methods are sometimes used for the preparation of negatives, and plates intended for negative making are sometimes used for prints.

As soon as Fox Talbot found that a greatly enhanced sensitiveness might be realised by the development of an invisible image produced by the exposure, the perfection of photographic processes in the different directions of the negative and the print was begun. The great sensitiveness that is so valuable in shortening the necessary exposure when taking a negative of objects that move or are likely to move, may be an actual drawback in a printing process because of the difficulty of keeping the sensitive surface absolutely free from any deposit where it is protected from the light. And in a print the colour of the image is of fundamental importance, while the deposit in a negative, though preferably black or grey, that it may affect all the constituents of light equally, may be, for example, of a rather dirty greenish shade of black without appreciable detriment, a colour that in a print would be highly objectionable.

The form of silver printing that most resembles the

making of negatives is called "bromide" printing, and the paper used "bromide" paper, the word "bromide" being a contraction of the expression bromide of silver, taking, as is usual in photography, the least important word or part of a word to represent the whole. Bromide paper is paper prepared with a suitable surface and then coated with a bromide of silver gelatine emulsion. It is therefore comparable to ordinary gelatine dry plates, but the emulsion is not made so sensitive as is usual for negative work. Nor is so much emulsion put upon the paper; it is unnecessary because the image or deposit produced does its duty twice over. In a negative or transparency the deposit has to be dense enough to produce its effect in regulating the light by a single passage of the light through it, but on a paper print, the light that illuminates it passes through the deposit to the white paper beneath, and is then reflected from the white surface and passes a second time through the deposit that forms the image, and so to the eye. If the deposit is of such a density that it stops four-fifths of the lights, then the one-fifth that can penetrate to the paper will suffer a like diminution in its passage back again, and only one-twenty-fifth of the light that would have appeared if there had been no deposit there will survive the treatment. Now when the light reflected from white paper is reduced to one-twenty-fifth of its brightness, that part of the white paper appears black. The blackness is not perhaps of the very inkiest blackness possible, but it is very near to it, and not many photographs have their darkest parts so black as this. But a deposit of silver in a negative that allows one-fifth of the light to pass through would be very inadequate indeed as a maximum density. In a negative we should be able to get a deposit that will allow only about one-hundredth of the light to pass, and sometimes even less than that.

The enhanced effect of the second passage through

a substance that impedes the passage of light, may be seen by lightly shading with a lead pencil a small patch on tracing paper. The difference in the darkness of the shading when it is held up to the window and looked through, and when it is pressed down upon a piece of white paper and looked on, will clearly illustrate this matter. These considerations with regard to the density of the deposit apply to all printing methods on paper or opaque surfaces, and show why it is often difficult and may be impossible to make a useful negative on a paper prepared for printing purposes. Paper that is specially intended for negative work has a thicker coating of emulsion put upon it. To obtain a useful negative instead of a print, it is necessary to considerably increase the duration of both the exposure and the development, that the image may be of the requisite density. Under these conditions printing papers of suitable quality may sometimes be advantageously used for the production of duplicate and especially enlarged negatives.

In the making of bromide prints the paper is exposed under the negative for a few seconds to a gas flame or other light of moderate intensity, or if an enlargement is being made, the image produced by the enlarging lantern or camera is allowed to fall upon it for a short time, the paper is developed, fixed, washed, and dried. The developer must be of such a nature that staining of the paper is absolutely avoided, and a little allowance has to be made in developing the image for the increase of its blackness by the fixing. This increase is due to the removal of the white particles of silver bromide which before fixing are interspersed among and underlie the black particles of the silver and give the image a greyish tinge.

To avoid the production of an unpleasant greenish black image, it is necessary to use only the minimum of potassium bromide as restrainer in the developer. Doubt-

less various developers give slightly different results, so far as a slight tinge of colour in the blackness of the image is concerned, but there is reason to suppose that these differences have been often stated to be very much greater than they really are. Organic developers are now generally used, though a little while ago there was a prejudice in favour of ferrous oxalate. But the limitation with regard to potassium bromide applies to them all, and it is therefore not possible to use such a restrainer in order to adjust the gradation of the print. It is possible, however, to reduce the contrast in a print by increasing the exposure, making the developer work more slowly by adding water to it, and stopping the development before it is complete. The image will then be of a warmer black than if development had been allowed to proceed further, and it follows therefore that the tint of the image depends upon the relationship that the gradation of the print bears to the gradation of the negative. The reddish tinge is presumably due to some of the particles which form the image being smaller than when the fully black image is obtained. But this redness, even when the exposure has been increased to four or eight times, is hardly observable, and the print appears to be of a good black unless a colder (or less red or bluer) black is put by the side of it and the two are compared.

The difference in colour obtainable by the variation of exposure and development within practical limits is very slight, and depends largely on the character of the negative. Those who prefer a brown to a black image must therefore generally alter the colour after the print has been otherwise finished. A very favourite method of doing this is to cause sulphur to combine with the metallic silver or some of it. This method was introduced and popularised by the Eastman Kodak Company, who recommended heating the print in a solution containing alum and sodium hyposulphite. Such a mixture deposits

sulphur copiously, and by its decomposition unstable compounds are produced which will slowly continue to give up sulphur to the silver. The method is slow, requiring many hours if the liquid is at the ordinary air temperature, and perhaps half an hour if heated.

Under these or any other practical conditions, silver combines very slowly with sulphur. It is therefore quicker, and to a certain extent a more controllable method, to add some other substance, such as chlorine or bromine, to the silver, and then to exchange this added substance for sulphur. This is the form of the sulphur method of toning that is at present generally preferred. If the substance that supplies the chlorine or its equivalent becomes insoluble by the loss of the chlorine that it gives up, then the residue of the reagent employed remains with the silver compound that is formed. By this and analogous methods, compounds of many metals may be added to the original silver image, metals such as iron, copper, uranium, vanadium, and antimony, and by acting on these, an image of almost any colour that may be desired can be obtained. Brown, blue, green, red, yellow, and intermediate and various shades of these colours are easily produced, and it is customary to describe such prints as toned bromide prints. But it is obvious that by such manipulation the character of the print has been vitally altered. The material of the image is no longer metallic silver, indeed it may have no silver or silver compound left in it, but it consists of more or less complex mixtures of substances, such as Prussian blue, the sulphides, ferrocyanides, chromates or other compounds of the metal or metals that may have been used. A pure silver image may last without perceptible change for twenty years or more, but a "toned bromide" print may deteriorate within twenty hours. Such prints prepared for exhibition have been known to change within a week or two to a notable degree as they hung upon the wall. A print ought to

be described as what it is, and not as what it was, but an attempt to do this in such cases would introduce difficulties, as there are no common names for many of the substances produced in toning, and some of the changes are of such a mixed character that it is impossible to say what remains in the film.

There is another kind of silver printing paper, though similar in many ways to bromide paper, the different varieties of which are commonly called "gas light papers." These generally, if not always, contain chloride of silver mixed with the bromide of silver, and are called "gas light" because they are so little sensitive that they may be cut up, put in the printing frames, and otherwise manipulated as necessary, in a room lit by ordinary gas light, with no other precaution than not allowing the gas light to shine directly upon them. The exposure under the negative may be to an ordinary gas flame for from one to about five minutes or longer at a distance of about twelve inches. The development may be carried out in a shaded part of the same room, or sometimes it is convenient to protect the paper from too much light during its manipulation, by seeing that one's own shadow always falls upon it. A chloro-bromide emulsion will give an image inclining to redness much more easily than a simple bromide emulsion; indeed it is possible with some to get a fully red or "red chalk" colour, by simply prolonging the exposure and developing with a developer that is very strongly and suitably restrained. A convenient method of exposure in such cases is by the burning of magnesium ribbon, and it may be necessary to use as much as six inches or more and to burn it at a distance of only five or six inches from the negative. But this method of modifying the colour is not advantageous beyond very narrow limits, because the greatly increased exposure tends to give a flat print, and the vigour of the image is so much reduced by the fixing bath that

it is difficult to know how far to develop to get the desired final result. The image in prints of this kind, being produced by development, consists of particles of metallic silver, and is therefore as amenable to after processes, such as toning, as the image on negatives and ordinary bromide paper.

The most common of all the methods of silver printing, although perhaps the most simple so far as manipulation is concerned, is the most complex from a chemical point of view. There is no development, the image is produced in its full intensity by simple exposure to light, and the process has for the last twenty years been called "printing-out," and the paper suitable for it "printing-out-papers" or "P.O.P." All photography was of the "printing-out" kind until the possibility of developing an invisible image was discovered. In these processes chloride of silver is used without any bromide, but it cannot be used alone, because the action of light upon chloride of silver is to cause some of the chlorine to separate from the compound, and this decomposition will not take place if the chloride of silver is absolutely pure and dry. There must be something present to which the chlorine can attach itself or it will not leave the silver salt, and if this "sensitiser," as it is called, is not sufficiently powerful, the chlorine that accumulates in it will act in the opposite direction to the light, and prevent the production of a fully coloured and vigorous image. But the presence of the sensitiser often leads to something more than just the simple change described, it produces other silver compounds, and these as well as the chloride of silver have to be taken into account. Thus the changes are mixed and complicated, and in no practical method have they been fully followed out. And when we add that the image as produced by simple exposure and fixing is an unpleasant red and has to be toned by the action of other substances upon it, it is not surprising that the

material of which the image finally consists is a mixture of unknown products. Although these printing-out silver processes can never merit the confidence that some other methods deserve, there has been such a vast experience with them, that from a practical point of view, they are not much inferior to developed silver prints, assuming proper care to be exercised in their production.

The earliest printing-out methods were "plain paper" processes, that is, there was no film on the paper, and for the sake of a brilliant image as distinguished from a "sunk in" appearance, the endeavour was made to keep the sensitive compounds on the surface rather than allow them to sink into the body of the paper. The sizing of the paper was found to be a very important factor in the matter, because it is this that confers the non-absorbent property and makes the difference between blotting paper and writing or printing paper. So sometimes a little sizing material such as gelatine or starch was added to the mixture used before the paper was coated with it. It was but a step from this to the use of albumen, used in the form of white of egg, and the getting of a definite film on the paper. It is not certainly known by whom or when albumen was first used, but both albumen and gelatine were used before 1851, and the earliest recorded use of albumen appears to date from about 1848.

The use of albumen is worthy of note, because for thirty or forty years albumenised paper was *the* silver printing paper, and the expression "silver print" meant a print on albumenised paper, and the word "photograph" in common language meant the same thing. The peculiar colours of the image obtained when such prints were toned in the ordinary way were known as "photographic purple," &c., and people so thoroughly associated these colours with "photographs," that when other printing

methods were introduced it was necessary to imitate these "photographic" colours in order to make people believe that the prints were photographs and to get them appreciated as such.

Albumenised silver paper was prepared by adding a little ammonium chloride to the whites of eggs, beating up well so that the animal membrane might be removed, and filtering the mixture through muslin or flannel into a flat dish so that a sufficient surface of it might be available. Each sheet of paper was gradually lowered upon the preparation until it floated on it, and then gradually raised and hung up to dry. To sensitise the paper it was floated on a rather strong solution of silver nitrate, and after a minute or two removed and hung up to dry. The silver nitrate coagulates the albumen or renders it insoluble in water in much the same way that "boiling" an egg affects the white of the egg, so that there is no fear of the albumen being dissolved off the paper in its subsequent treatment. It forms silver chloride and ammonium nitrate with the ammonium chloride, it produces a compound of albumen containing silver, so that all these things with an excess of silver nitrate remain on the paper. What chemical changes take place during the exposure are not known, but probably the chief part played by the silver nitrate is to facilitate the decomposition of the other silver compounds into coloured substances. A print made on such paper and fixed in hyposulphite of soda would show an image of a disagreeable red colour, and in order to get a more agreeable purple, brown, sepia, or an approximation to black, it was usual to tone it by putting it into a suitable solution containing gold, though sometimes platinum and other metals were used. By far the greater number of photographs and all the small portraits of a generation or so ago were made by this method. Some lasted ten, twenty, or even thirty years without obvious

change, but the greater number showed signs of fading within a shorter period; and if carelessly prepared or not properly washed, or pasted upon an inferior mount, or pasted with sour paste, or otherwise subjected to adverse influences, they might last no more than a few months before showing signs of change.

As albumenised paper became more largely used, it was prepared commercially ready for sensitising, and eventually it was sold ready sensitised, and as when sensitised it would not keep in good condition for more than a day or two, preservatives, generally citric acid, were employed. But when the demand for printing papers increased, it was obvious that the manipulation of single sheets of paper was disadvantageous, and that the method to aim at was the preparation in bulk of an emulsion that could be coated upon the paper by machinery. This led to the introduction of gelatino-chloride and collodio-chloride printing papers, and as these would keep in good condition longer than sensitised albumen paper, and gave results that were generally considered richer in colour and in general appearance, everything was in their favour. These papers were introduced between 1885 and 1890 in America, and in England in 1891 by the Ilford Company. Other firms soon arranged for the manufacture of them, and albumenised silver paper gradually became a thing of the past. It is papers of this type that are now referred to by the generic title of printing-out-papers or P.O.P.

Printing-out-papers are known by all sorts of fancy names, and presumably are prepared by many different formulæ, but the general method of preparation is to introduce into the medium a chloride, nitrate of silver (which forms chloride of silver by reacting with the chloride; but more nitrate of silver is added than is sufficient to complete this change, so that there remains some unchanged silver nitrate), an organic salt such as

a citrate or a tartrate (to give more body to the image), and citric acid which preserves the sensitive salts from a too rapid spontaneous change. This emulsion is spread upon paper that has already been prepared by coating it with a suitable substance that gives it a smooth and slightly absorbent surface.

When such paper is exposed under a negative until the image is somewhat darker than is desired—for it loses in depth in the after-treatment—and then fixed, the colour will be of an unpleasant reddish colour, much as in the case of albumenised paper. Hence the need for toning. The chloride of gold used for this purpose is always mixed in solution with another substance, preferably ammonium sulphocyanide, and when the washed print is put into the solution, gold is deposited upon the image in a form which appears blue, and the red of the image is thus modified to the rich nondescript colours that are so familiar. The print is then fixed in hyposulphite of soda to remove all the silver compounds that are sensitive to light, and well washed.

Gold may be deposited by such means as just described in either a bluish or a reddish form, and it appears that the difference in colour is due to a difference in the size of the particles in which it is deposited. In toning it is the bluish form only that is effective, and the rapidity of action of the toning bath is arranged in order to secure this. But as the change of colour seems to be due to the deposition of particles of a certain size rather than of a certain substance, other substances besides gold might be expected to serve, and so indeed they will. It appears that the earliest toning baths used, about sixty years ago, did not contain gold at all, or at least only as an alternative, the change of colour being brought about by adding to the fixing bath some substance that would cause the deposition of sulphur from it, so that toning, by the deposition of sulphur, and fixing went on

STONEHENGE

AS SEEN FROM AN AEROPLANE.

Photographs from balloons and sometimes from kites have been made since many years ago for military surveying purposes. Whether or not aeroplanes will prove more advantageous for such work remains to be seen.

simultaneously. A little acid added to the fixing bath will do this; but simple acid is not advisable; and it was usual to add more than one thing and sometimes many—ferric chloride and silver nitrate, or iodine and silver nitrate, with the addition of lead nitrate, or gold chloride and silver nitrate. Such baths are called "combined," because they serve the double purpose of toning and fixing. Even to the present day it is usual to give formulæ for combined baths, to draw attention to the rich colours that they give, and to warn photographers not to use them. Judging merely by the colour that they give, these baths improve by use, and they continue to give satisfactory results to the eye after probably all the gold has been removed from them. It is impossible to follow all the changes that may take place, but they are certainly many more than when the toning and fixing solutions are kept separate. The resulting image, though it may be of a pleasant colour, is often very unstable.

The self-toning papers now so common have the necessary gold salt added to the emulsion. Some of these are put in a weak solution of common salt before fixing to allow the toning to take place, others may be fixed straight away. Although the gold salt in the latter case goes into the hyposulphite solution and so forms a kind of combined bath, the self-toning paper has the advantage that every piece of paper takes into the fixing bath the gold necessary for its toning, so that the bath cannot be used after all its gold has been removed from it, a very likely occurrence with the ordinary combined bath. There can be no doubt that the safest course is to keep the toning and fixing quite separate, for then the possible changes are simplified, and if the toning bath is too weak or is getting exhausted its slower or incomplete action is shown at once.

Although the sensitive papers now under consideration are printing-out-papers, it is possible to partly print out

and then to complete the production of the image by development with an alkaline developer. The Paget Prize Plate Company, who introduced this method of work in 1893, say that "the actual time of exposure may be anything from that necessary to fully print out, down to that only sufficient to produce a faint image of the stronger details." If the developer were applied to such a print, the image would be at once buried in blackness. It is necessary to soak the print before development in a rather strong solution of potassium bromide, in order to convert the silver salts as far as possible into bromide, and also to use a large proportion of potassium bromide in the developer. The developed print then needs to be toned and fixed as if it had been produced by a full exposure without development.

There is a curious method of silver printing, or rather of using silver paper for getting first a negative and from it a print, that is generally called "Playertype" after Mr. J. Hort Player who described the method in 1896. Mr. Player did much to perfect the method, and produced some excellent results by its means. The strange detail in the process is that the sensitive paper is put face downwards on to the original of which a photographic copy is desired, and then exposed so that the light passes through the sensitive paper before it gets to the original. It might be thought that the paper would be completely fogged as there is nothing over it to regulate the action of the light, and so indeed it is, but not to such an extent as to render useless the image that is produced by the light reflected from the surface of the original. By this means a negative results, and from this a print is produced by exposure of the paper under the negative in the usual way. It is obvious that the copy can only be of the same size as the original. The special advantage of the method is that illustrations or letterpress in books, pencil drawings, photographic prints, or anything of the sort can be copied

even if on opaque mounts, and without interference from any printing or device that may be on the back of them.

The method that Mr. Player found to be the most successful, was to place a piece of gelatino-chloride paper face downwards on the engraving to be copied; on the top a yellow screen was put with an extra sheet of glass if necessary to press the whole into close contact by its weight, and exposure was made to daylight. With a green screen gas-light might be used. Hydroquinone was used as developer with a little potassium iodide added to it. All these details are such as would tend to increase the contrast in the negative produced, and so to get vigorous detail in spite of the general fog. That such a process should be practically possible, seems to indicate that a considerable amount of light may pass through a sensitive film without affecting it, although the light that has passed through is well able to produce its characteristic result when it is sent, by reflection from the surface beneath, through the film a second time. That this really is so may be confirmed in other ways.

CHAPTER XII

OTHER PRINTING METHODS

It is possible, directly or indirectly, to get photographic prints in almost any material. Some processes are not worth following up because they give unpleasant colours, others because they are too costly and offer no commensurate advantage, and others because they are too tedious or the result is too unstable, or for some such practical reason.

Silver salts were the earliest sensitive compounds employed, and they have always retained the foremost position, partly perhaps because they furnish processes that are easy to work by those who are able to make negatives, and partly because the general public has got used to them. The colours of the image that they give are often peculiar to themselves, but they are so much appreciated that other methods which naturally would give colours more welcome to educated eyes, have had to imitate the appearance of silver prints in order to gain a measure of patronage. The chief disadvantage that all silver prints suffer from is their want of stability. In this they vary much according to the method of their production and the care exercised in the preparation of them. Some will last for a year or two, some for a decade or two, and a very small proportion may be in fair condition after a generation. Although imperfect fixing and washing certainly tend to shorten the life of a silver print, it is impossible to say definitely why there should be so much variation in the permanence of prints produced apparently with due care. The fact is that finely divided metallic silver and silver

compounds are susceptible to the action of many adverse conditions, and it is not always possible to guard against these. The superior stability of negatives is occasionally mentioned as evidence that silver prints might be more permanent, but the two cases are very different. In the negative there is a much greater quantity of silver, and it is more thoroughly embedded in the gelatine and therefore better protected from outside influences, and on the glass side its protection is perfect. The print is generally mounted, and the paste used as well as the card may contain deleterious matter. Therefore all the chances of a long life are in favour of the negative.

The only way to ensure permanency is to give up silver altogether so far as the print is concerned. Platinum and carbon are two substances that are as little liable to change as any material, and both of these are practically available and give their names to processes that are extensively used at the present time. They can, however, only be employed indirectly, for no platinum or carbon compound is usefully sensitive to light.

Platinum, from its inertness, seemed such an advantageous material to use for the image of the print, that we find attempts to formulate a method for it as far back as 1845. These early experiments failed because the compound of platinum with the maximum amount of chlorine was used, so that even if some of its chlorine was removed directly or indirectly by the agency of light, the soluble compound with less chlorine in it was produced, and the amount of metal deposited was very slight, if any. Some of them failed because it was sought to get a sensitive platinum compound, and to get the visible image produced during the exposure. The conditions necessary for success were realised by Mr. W. Willis in 1873, and by 1880 he had succeeded in doing without the addition of any silver or lead compound, which till then he had found helpful.

The sensitive substance that is used in platinum paper is ferric oxalate, and this dissolved in water with the platinum salt forms a yellow solution which is applied to the surface of a suitable paper. The prepared paper is yellow on the coated side, and it is notable that the ordinary papers for platinum printing have no film, as of gelatine or albumen, on the surface; the substances applied are actually on the paper itself and penetrate a little way into it. To prevent the coating solution from penetrating too far, the paper is suitably sized. When the paper is exposed to light, the iron salt, that is the ferric oxalate, is decomposed so that a part of the substance that is combined with the iron is driven off from it, and the iron in the compound that remains, ferrous oxalate, is now able under suitable conditions to combine with something else. These conditions are brought about when the exposed print is developed, and the iron compound, being in the immediate presence of the platinum salt, takes chlorine from it and leaves the metal platinum as a grey or black deposit to form the image. The platinum compound used is the chloride that contains the least possible proportion of chlorine, so that no chlorine whatever can be taken from it without a corresponding deposition of the metal. The developed print is put into weak hydrochloric acid, so that all the substances in the paper, except the metallic platinum which is quite insoluble, may be dissolved out from it; the acid is changed a few times that its action may be complete, the acid is washed away with water, and the print is dried.

By varying what may be called the minor conditions, paper may be prepared so that it is advantageously developed on either a hot or a cold solution of the developing agent, and by the addition of a very small proportion of mercuric chloride to the solution with which the paper is coated, and a few little adjustments in other details, the metallic platinum will be deposited so that a reddish

brown or "sepia" image is obtained instead of black. This coloured deposit consists of pure platinum, and its colour is doubtless due to the particles of metal being smaller than when the image is black.

The permanent nature of the platinum image can be inferred from the fact that no method has yet been found of altering it or removing a part of it, as, for example, by dissolving it. Aqua regia will dissolve platinum, but if a platinum print is put into it, the paper is disintegrated and destroyed before the image is dissolved. Although it is impossible to get platinum to combine with anything and so to tone the print by any of the methods that work so easily with silver prints, it is possible to deposit other things upon the platinum. If a liquid is just about to deposit a constituent that it has in solution and a platinum print is put into it, the platinum will cause the deposition to take place in its immediate presence a little sooner than it otherwise would, and in this way gold which is bluish, uranium ferrocyanide which is a reddish brown, and doubtless many other things can be added to the platinum, and so the colour of the image may be somewhat changed. Any substance so added can be removed again if there are means suitable for the purpose, and the platinum will remain unchanged.

It is very difficult to remove the last small portions of the iron salts which remain in the paper after development, and however carefully the prints are washed there will be a minute trace of iron compound that cannot be got rid of, and this will cling especially where the platinum has been deposited. By soaking the print in a solution of gallic acid or an extract of catechu this ferruginous residue is turned to a brown compound, and this imparts a warm tone to the print. Some platinum prints, especially those that have not been very carefully washed or have been mounted on inferior cardboard, have been noticed to gradually change to a yellowish brown

colour, that really appears as if the print were fading like a silver print. But this change appears to be due to the small amount of iron left in the print, and by the application of dilute acid and chlorine it can be entirely removed and the original colour restored in all its brilliance.

Thus the platinum image is not only able to resist all detrimental atmospheric influences, but there is no method known by which it can be attacked. As the sensitive substance is put directly upon the paper, the paper must be of excellent quality, free from extraneous matter and fibres of inferior quality, for if any such matters were present they would affect the process and show flaws in the print. The suitability of the paper is therefore a practical guarantee of its purity, and as we know that linen[1] will last for thousands of years, as demonstrated for example in the present condition of the cloths on mummies, there seems every reason to suppose that if platinum prints had been made in Abraham's time, or when Egypt was at the height of its glory, they might, if preserved with reasonable care, have been available for our information at the present day.

Platinum printing is essentially an iron process, because it is the iron compound that is changed by exposure to the light, and it is the new iron compound (the ferrous salt) which at a second stage of the process acts upon the platinum salt and gives a deposit of the metal. The platinum salt may therefore be omitted from the coating on the paper and be applied after the exposure, and a practical method was actually worked out on these lines a short time ago, but it was withdrawn as it was not on the whole advantageous. Instead of a platinum salt which gives an image in metallic platinum, a silver salt may be used and the image obtained in metallic silver,

[1] Linen and paper consist almost entirely of the same substance, namely, cellulose.

or a gold salt will give an image in metallic gold. These processes have been dignified with names, but the silver method is not used because other methods of getting silver images are preferable, and the gold method is useless because gold images have so little substance or body in them, and they are generally of unsuitable colours. For such methods as these last a citrate instead of an oxalate of iron is often preferred, but the principle of the method and the character of the change produced by light is exactly the same.

If paper coated with the iron salt only is exposed under a negative and then plunged into a solution of potassium ferricyanide, the ferrous salt that the light has produced will give a dark blue insoluble deposit with the ferricyanide, while the original salt unacted on by light will give only a soluble product. If then everything is washed away that water will dissolve, a dark blue image is obtained, the colour of which cannot be distinguished by the eye from Prussian blue and indeed is quite analogous to it. The ferricyanide may be mixed with the iron salt and the paper coated with the mixture, then after exposure the print needs only to be washed in water to give the blue image. Paper of this character is extensively used for copying engineers' and architects' drawings, because as no costly substances are used in its preparation it is cheap, and its manipulation is very simple. The fact that the image is blue is no detriment for such purposes, but those who are acquainted with the chemistry of iron compounds would find no difficulty in modifying the colour if the blue were objectionable.

The use of iron compounds as sensitive substances gives a great variety of possibilities to the photographer, for there are other applications of them to which we have not referred, but the importance of these is far surpassed, so far as practical work is concerned, by potassium bichromate. We shall see in this and the following chapter in

how many different ways this substance is utilised. When a gelatine film is impregnated with it, the gelatine remains soluble in hot water, but if the impregnated film is exposed to light, the bichromate is decomposed and the product of its decomposition renders the gelatine insoluble in water. If therefore a bichromated film is exposed in some parts and not in others, it may be "developed" by means of hot water, and if the gelatine had previously been mixed with a pigment such as lamp-black, those parts of the gelatine film that had been made insoluble by the exposure would remain with the pigment, while the rest would be washed away. This is the essence of "carbon" or "pigment" printing, and the procedure was patented in 1855 by Poitevin. It seems simple at first sight, but a little consideration will show that this crude process will not work. The insolubility obviously begins at the surface of the gelatine and penetrates downwards into the film as the light continues to act. If in the darkest parts of the print the light has produced insolubility right through the film, in all the less dark parts which represent the middle tones and the high lights, the insolubility will not extend to the lower surface of the film, and the insoluble gelatine will lie upon that portion that remains soluble beneath it. When the hot water is applied, it dissolves this soluble part, and the insoluble part supported by it floats away. In 1858 it was found that this difficulty could be remedied by exposing through the paper upon which the gelatine film was supported, as then all the parts made insoluble were actually on the paper. Good "carbon" or "pigment" prints were made in this way, but, to say the least of it, it was an awkward method, and the next step in advance was to expose from the front as usual, and to coat the print with collodion before it was developed. In the hot water the film of insoluble pigmented gelatine would float off from the paper on which it was originally, but the collodion held it together, and it could be caught

upon another sheet of paper coated with gelatine to form the final print. Thus the principles of carbon printing were well understood at this time, but it was not until 1864, when Mr. J. W. Swan introduced a few modifications, that the process became suitable for commercial work on a considerable scale. The method as at present practised is Sir J. W. Swan's, though it has been improved in a few details.

"Carbon tissue" is paper coated with a substantial layer of gelatine which has been mixed, before application to the paper and while in solution in warm water, with a sufficiency of any suitable pigment. The only restrictions as to the character of the pigment that can be used is that it must not injure the gelatine, and it must be unaffected by either warm water or potassium bichromate or alum, and this gives such a wide choice that it is possible to prepare a tissue of almost any colour or shade. The bichromate that confers the sensitiveness may be mixed with the melted jelly before the paper is coated, or the coated paper may be treated with a solution of the bichromate. The sensitive tissue is exposed to light under the negative as usual, but, as the pigment in the gelatine makes it so dark, the slight change of colour that light produces in the potassium bichromate is not visible. The progress of the action of the light is therefore gauged by an actinometer, in which a small surface of sensitive silver paper is exposed to light through a hole in a plate that covers it, and the darkening of the paper is watched until it is equal to a painted tint by the side of the hole. The exposure of the carbon print may have to be continued while the silver paper in the actinometer darkens to the comparison colour several times according to the density of the negative and the print required. A piece of paper with a smooth coating of insoluble gelatine on one side of it, is plunged into cold water with the exposed carbon tissue; after a minute or two they are withdrawn from the water

face to face in contact, and the water between them is forced out by putting them on a flat surface and stroking them repeatedly with a flexible edge of india-rubber. The two papers now stuck together are next put into warm water, which soon penetrates to the soluble gelatine and begins to dissolve it, so that the original paper may be stripped off, leaving the bulk of the pigmented gelatine on the second sheet, with what was the face of the gelatine during the exposure secured to it. The warm water gradually dissolves away the gelatine that has been left soluble by the exposure and the picture gradually appears. When fully developed, the print is put into alum solution to harden the gelatine, washed, and hung up to dry.

A carbon print made as just described is called a single transfer print, because the exposed gelatine film is transferred once, namely, from the paper that carried it during the exposure to the paper upon which it was developed and finally remains as the finished print. The effect of this transference is of great importance. If the reader will write on a piece of paper, and, while the writing is still wet, put blotting-paper upon it, the writing will be partially transferred to the blotting-paper, but the transferred writing will be laterally inverted, a condition that has been described in detail at page 87. The writing will progress from right to left instead of from left to right, and every letter will be as it were turned over sideways. The single transfer print will be laterally inverted in exactly the same way, and the effect in a portrait, for example, would be to make the person appear left-handed, and to change over every detail from right to left and left to right. Such inversion is of course not to be permitted. If the writing on the blotting-paper is held up in front of a looking-glass, the reflection will be seen to be correct, because the mirror produces a second lateral inversion, as we have already seen. When many carbon prints are wanted, as in the

reproduction of pictures for publication and other similar cases, it is customary to correct the inversion by photographing the reflection of the picture instead of the picture itself. The mirror is put close to the lens, because in that position it needs to be but little larger than the lens itself, and it is fixed at an angle of 45 degrees. The negative so produced would give a laterally inverted print by any direct printing process like those we have previously considered, but the transfer in the carbon process puts the image into the correct position. The two inversions are exactly analogous to turning a piece of paper over twice, when the second turn restores it to its original position.

But if a carbon print is wanted from an ordinary negative, then the necessary second inversion is obtained by a second transfer. The exposed tissue is put down upon a "temporary support" for development instead of upon the paper it is to remain on, and retransferred from this, after development, to the final support. The surface of the temporary support is so prepared by thoroughly cleaning it and then giving it an imperceptible coating of wax which is almost entirely polished off, that it will hold the picture securely, but not quite so tenaciously as the final support. This is coated with a solution of slightly hardened gelatine, and when it and the developed picture are thoroughly soaked in water they are brought together under water, withdrawn, and as much as possible of the water between them is pushed out by a sweeping movement of an india-rubber-edged scraper (called a squeegee). When quite dry, the two supports are separated and the print adheres firmly to the final support. The temporary support generally used is flexible, somewhat like thick paper with a hard, smooth surface, and the final support may be almost any surface, as paper, celluloid, ivory, opal glass, porcelain, plain glass for transparencies, &c. As the picture is thoroughly washed

during development on its temporary support, there is no soluble matter left in it to contaminate the surface to which it is transferred.

There is a peculiar circumstance that has to be borne in mind when dealing with gelatine that has been made sensitive to light by means of a bichromate. If we may compare inanimate things with animate, we may say that of those substances that are acted upon by light there are some that change sulkily and unwillingly, and as soon as the force that obliges them to alter is withdrawn they revert to their original condition. There are others that welcome change, and if only they are started will continue to alter their condition even after the force is withdrawn. And there are others that take things as they come and care nothing either one way or the other. The gelatino-bromide plate belongs to the last section, for it will remain as it is for years, and if exposed for the production of a negative, it will remain in its changed condition for years, ready for development. Gelatine with bichromate belongs to the second section. The change only needs to be started by light and it will continue when the light is withdrawn, though obviously not so quickly as if the light were still at work upon it. This continuing action is of very practical importance and must be allowed for if development does not take place within an hour or so of exposure. If a print has had only the tenth of the necessary exposure and it is put away in the dark for a day or perhaps two days, it will be found to be as if fully exposed. This circumstance has been utilised when the light is poor or many prints are wanted from the same negative, but as the rate at which the change continues depends upon the hygrometric condition of the gelatine and perhaps upon other circumstances which are practically uncontrollable, the result is very uncertain, and at the present time is probably never taken advantage of. If the partly exposed print is kept really dry by chemical

means, by shutting it up with a powerful absorbent of moisture, then the change is arrested.

The permanency of a carbon print obviously depends upon the character of the pigment used. At first, when the peculiar colours of silver prints were imitated, sufficient care was not exercised in this direction, the pigments were mixtures containing fugitive constituents, and of course the colour of the prints altered in the course of time. A more judicious choice is made at the present time, but this possibility of the presence of an unstable substance must always remain, and the photographer has to trust to the maker of the tissue. If carbon only, such as Indian ink or lamp-black, is used, then the pigment is thoroughly satisfactory, and so far as permanency is concerned we have to consider only the gelatine film that carries it and the paper that supports the film. The paper need not be of that perfect quality that is necessary in platinum printing, because the image is not produced or mounted in immediate contact with it, and the very fact that there is a film to carry the image is an added complication. A carbon print has therefore more points of possible attack than a platinum print, and although platinum and carbon may well be associated together as the two processes that yield permanent results, platinum must always be the more desirable when the distant future is considered.

The carbon process is one that lends itself to many modifications, some of which are curious and some useful. As an example of the former the development by digestion instead of by hot water may be noted. By putting the print into water containing about one per cent. of pepsin and one and a half per cent. of hydrochloric acid at the temperature of a moderate summer's day, the gelatine that remains soluble in hot water will be attacked and dissolved away in about three hours.

The ozotype process was introduced by Mr. Thomas

Manly in 1899, and has the advantage that there is no transfer of the image produced by exposure, and therefore no question of lateral inversion, and as the effect of the exposure to light is visible, there is no need of an actinometer. The pigment in its film of gelatine is not made sensitive at all as in the ordinary carbon process. The paper upon which the print is to be is suitably sized and rendered sensitive with a solution of potassium bichromate, mixed, however, with a manganese salt. It is exposed to light under the negative until the light brown image is of suitable density, and then washed until all the unattacked bichromate is removed. The print is now not sensitive to light and may remain for any convenient time, up to about two months, before it is proceeded with. To complete the print, the exposed sheet and a sheet coated with pigmented gelatine are immersed in water in which have been dissolved a little acid, a little alum, and some ferrous sulphate, brought out of the solution face to face, and the excess of the liquid is driven out from between them with a squeegee. In half an hour or so the print is put into hot water, the paper backing of the gelatine is stripped off and development completed as in the ordinary process. During the waiting before development, the acid dissolves the chromium salt that has been changed by light and so enables it to slowly penetrate into the overlying film of pigmented gelatine and render insoluble those parts that it comes into contact with. The other substances present assist or serve to regulate the changes that take place.

A few years after Mr. Manly introduced the ozotype process, he devised the ozobrome process, by means of which an ordinary bromide print may be changed into a carbon print. This method offers the considerable advantage that the exposure necessary is only a few seconds, or it may be a minute or so, to artificial light,

instead of the prolonged exposure to daylight necessary when the bichromated gelatine itself is the compound acted upon by the light. Thus it is possible from a small negative to make an enlarged carbon print without the need for an enlarged negative, which is necessary for the preparation of a carbon enlargement in the ordinary way. If the bromide print is already prepared, no exposure to light is necessary. A sheet of paper that carries a film of gelatine is soaked in a solution containing a bichromate, a ferricyanide, and a bromide, and then pressed into close contact with the bromide print. After a few minutes the print may be developed in hot water as if it were an ordinary carbon print. The silver of the bromide print produces an effect in the bichromate similar to the effect of light, and so it indirectly renders the gelatine insoluble and fixes upon itself a due proportion of the pigmented gelatine that resists the action of the hot water. Instead of simple development, the two papers may be peeled apart; the one that bears the pigmented gelatine may be treated exactly as an ordinary exposed carbon print, that is, mounted and developed, while the bromide print which has its silver now changed into a compound of silver may be brought back to its original condition by any ordinary developer, and will then furnish other carbon prints by repeating the process, all without any need for exposure to light.

About four years ago the Rotary Photographic Company put upon the market a bromide paper that had the pigment in the film with the silver bromide. The paper was exposed and developed as for a bromide print, then put into a bichromate solution for a suitable time and washed. The metallic silver of the developed image acted upon the bichromate, and the print was mounted and developed like an ordinary carbon print, thus getting a carbon enlargement with the same facilities concerning

the exposure as if only a bromide print were being prepared, and by the use of only a single sheet of coated paper.

It was pointed out above that, as the light when it acts on a film of gelatine made sensitive by bichromate of potassium produces insolubility from the outer surface of the film downwards, it is necessary to support the outer surface of the film during development to prevent it from being washed away by the solution of the soluble gelatine beneath it. But these conditions may be modified if the film is kept thin and allowed to enter into the paper that supports it to a slight extent. About twenty years ago M. Artigue introduced a kind of carbon tissue, "papier-velours," which after exposure was developed as it was, without transfer, by pouring over it a kind of soup made of fine sawdust and water, the slight friction carrying away the parts not made sufficiently insoluble by the exposure to light to withstand the action. The method by which this paper was prepared has not been published, but it led to a revival of the gum-bichromate process which Pouncy had worked at long before. The paper is coated in this case with the pigment mixed with a gum mucilage rendered sensitive with the bichromate, exposed under the negative, and developed by passing water over it, and assisting the removal of the still soluble gum with the pigment it contains by the application of a soft brush. Gum, unlike gelatine, does not require warm water to dissolve it, and as the insolubility produced by exposure is relative rather than absolute, more or less can be removed in the various parts of the picture at the pleasure of the worker. Such selective development partakes of the nature of painting by hand but in the reverse direction, because the effect of the brush is to remove the pigment and not to add it. This possibility of control is much valued by those who are interested in photography chiefly or wholly as a method

DISTORTION AT THE EDGES OF THE PLATE DUE TO ITS FLATNESS

The rays that form the image fall obliquely on the edges of the plate, and the image is thus drawn out in a radial direction. The upper figure is the photograph of a sphere (a terrestrial globe) taken under these conditions, and it appears as if it were egg-shaped. The cylinder in the lower figure is really higher than it is wide, but it appears to be wider than it is high. If a row of persons is photographed, each individual except the middle one is represented as wider (or stouter) than he really is in proportion to his height, and this effect increases towards the edges of the plate.

of pictorial expression, because it enables them to supplement photography with such handwork as their skill and artistic feeling may indicate as desirable. Possibly also it is valued by some as a means of correcting the errors that they have committed in the photographic process.

In the methods considered so far the pigment is put into the gelatine or gum before the film is made, the film is applied as a whole, and what is not wanted is dissolved away. There are also methods of getting pigment prints in which the pigment is applied to the film after the exposure to light. If a film of gelatine made sensitive to light by means of potassium bichromate is exposed to light under a negative and then put into water, those parts where the light has acted will absorb less water than the other parts, and if the surface water is wiped away in proportion as the parts absorb less water so will they the more rapidly allow of the deposition of greasy matter upon them. The greasy matter may contain pigment, it may in fact be an oil paint or printers' ink. This fact has been known for some fifty years or so, but it is only quite recently, in 1904, that Mr. G. E. H. Rawlins proposed to utilise the process for the preparation of photographic prints. Paper coated with gelatine is put into a solution of potassium bichromate to sensitise it, dried, exposed under the negative, washed in several changes of water to remove the unchanged bichromate, well soaked in water and wiped dry on its surface. It is now ready to receive the ink. This may be dabbed on with a pad, or rolled on, or brushed on. If dabbed on all over the print and an ordinary printers' roller is passed lightly over it a few times, the paint will gradually leave the unexposed parts and accumulate on the shadows. By letting a moderately stiff brush fall upon the print from a height of about an inch and wiping the brush as required, paint may be removed.

By such methods as these the pigment may be applied according to the taste of the worker.

In 1908, Mr. C. Welborne Piper devised a practical method of applying this process to bromide prints, after the manner in which Mr. Manly had adapted his ozotype process. The bromide print is bleached in a solution similar to Mr. Manly's but with a little alum and citric acid added to it, soaked for a short time in dilute sulphuric acid and then the silver salt is dissolved out in a fixing bath. The metallic silver of the original image has by the aid of the first solution used, which contains the bichromate, acted upon the gelatine and bichromate very much as light would have done, so that wherever the silver was and in proportion to its quantity, the gelatine is less ready to absorb water and more ready to receive a greasy ink. The application of the pigment is exactly as before, and the advantage is, as in the case of ozobrome, that the very small exposure to light necessary for the production of a bromide print suffices instead of the protracted exposure necessary when the light acts directly upon the bichromate.

These processes may be modified in detail but the principle remains the same. There are, however, two other distinct properties of potassium bichromate of which good use has been made in the past. Dextrine as usually obtained is a sugary, sticky substance, and if this is mixed with a bichromate it will form a sticky film upon any surface to which it is applied, as sticky as if the bichromate were not present. Exposure to light changes the bichromate as usual, and the products of its decomposition diminish the stickiness of the film in proportion to their quantity. By "dusting on," or moving by means of a soft brush, a finely ground pigment, such as black lead, over the surface of such a film, the powder will

adhere in proportion as the film remains sticky, and in this way an excellent image may be produced.

If paper or other material is coated with or soaked in a bichromate solution and exposed after drying it, the bichromate will be decomposed in proportion to the amount of light action, as in all the methods already described. Instead of utilising the products of decomposition of the bichromate to render such substances as gelatine, gum, or dextrine less soluble or less able to absorb water, it is possible to utilise the unchanged bichromate for the production of an image. The bichromate is a powerful oxidiser, and if allowed to act upon aniline will oxidise it into a mixture of dark substances, chiefly tarry matter and aniline purple. So by allowing the vapour of aniline to come into contact with the exposed bichromated sheet, the parts where the bichromate remains are blackened. It will be noticed that in this as in the "dusting on" process, the dark parts of the prints are those where the light has not acted, so that the print is a reproduction of the plate through which the exposure was made, instead of having its lights and darks reversed as is more usual. For this reason, the "dusting on" process has been used for the reproduction of negatives, and the aniline process for the copying of engineers' drawings.

These latter processes, and others that might be mentioned, are probably never used at the present time. This neglect of methods of work that have done excellent service is due to a kind of survival of the fittest. The misfortune is that the "fittest" is not always the really best, but merely the one that happens to best "fit" the existing conditions, one of which may be a general want of skill and knowledge. Processes that have passed into disuse must therefore not always be condemned as inferior

to the others that have taken their places. The greater number of those who practise photography now want as much as possible done for them, and the little that they have to do to be made as simple and as mechanical as possible. This fact will account for many circumstances in connection with photographic work.

CHAPTER XIII

PHOTO-MECHANICAL PRINTING

THE problem of multiplying copies of photographs was present in the minds of many of the pioneers of the art. The preparation of a negative from which prints may be made by the photographic processes described in the previous chapters was a step in this direction. If a large number of prints is needed, as for publication purposes, it is usual to make duplicate negatives so that several prints may be simultaneously produced, but in any case the operation is tedious and the results comparatively costly, especially if a "printing-out" method is employed. It was realised nearly a hundred years ago that it was desirable to be able to prepare a plate by photographic means that would enable impressions to be obtained in an ordinary printing press, so that the accuracy and rapidity of photography might be combined with the facility of common printing methods. The elder Niépce did something, Fox Talbot did a good deal more of work in this direction, and in the early fifties there was realised a measure of success that was distinctly encouraging and that soon brought innumerable workers into the field. In one direction it was sought to photograph directly on to the block for the wood engraver instead of drawing upon it by hand, but this kind of work is now very nearly obsolete, for photography has superseded not only the draughtsman but the wood engraver too, except to an exceedingly small extent. Steel and copper plate engraving has followed wood cutting, and one may say in general

language that all illustrations for book or similar work are now produced photographically. We do not propose to trace the history of the development of modern methods of illustration, for this is a very extensive subject, but rather to give some idea of the principles upon which the chief of them are based.

If a print is made from a negative by any photographic process, the result is generally called a photographic print or simply a photograph; but if from a photograph or negative a plate or a block is prepared and impressions are taken from this, the result is called a photo-mechanical print, because although it has a photographic origin, the print itself is prepared by mechanical means. We have seen that a carbon print is prepared by treating a pigmented film of gelatine with potassium bichromate, exposing to light under a negative, and then dissolving away with hot water those parts of the film that have not been acted upon by the light and therefore remain soluble. The darkness of the image depends entirely upon the thickness of the film that has been affected by light and so made insoluble. The dark shadows are represented by a comparatively thick layer of the pigmented gelatine, the medium tones by a thinner layer, and any parts of the image that are white have no deposit at all upon them, for there it has all been dissolved away. The image in fact is in relief, and the height of the relief is proportional to its darkness. This is a photographic print; but if an exactly similar relief is made by pouring melted pigmented gelatine into a mould and allowing it to set and dry, the print is a mechanical print, and if the mould is obtained by photographic means, it is a photo-mechanical print. The "casting" method of getting prints is called Woodburytype, after the name of the inventor. A gelatine relief is prepared in very much the same way as a carbon print is made, but in higher relief, and this when dry is placed with a sheet of lead in a hydraulic press, and the

two are forced together until the relief is driven into the lead. Gelatine when dry is very tough and hard and gives a clean impression. The lead plate is printed from by pouring a pool of melted pigmented gelatine on it, putting the sheet of paper on top, and subjecting them to pressure in an ordinary printing press. The gelatine sets and the paper with the print upon it can be removed from the mould and hung up to dry. It is clear why the relief used in making the mould must be "higher" or thicker than an ordinary print, for it has when dry to produce a mould that will hold enough gelatine *jelly* to give the print, and the jelly shrinks very considerably as it dries.

In the "Stannotype" process the need for the hydraulic press is dispensed with. The gelatine relief is made as before and the mould is built up on it by passing it with a sheet of tinfoil between india-rubber rollers, so that the foil is pressed all over into close contact with its surface, and this tinfoil is then strengthened by the deposition of a metal upon it and backing it up with a suitable resinous body. Or the gelatine relief may itself be used as the mould by coating it with india-rubber cement and covering it with tinfoil pressed thoroughly down upon its surface.

There is one important feature of Woodburytype prints, namely that they are exactly analogous when finished to photographic prints made by the carbon process. They give a perfect gradation of unbroken tint, thus resembling photographic prints and differing from photo-mechanical prints produced by any other process. The "ink" is not what is usually understood by that term, but gelatine mixed with the required pigment. In all other mechanical processes printers' ink is used, that is a mixture that has the general characteristics of an oil paint.

The "oil printing" methods described in the last chapter show that when a gelatine film is sensitised by means of potassium bichromate and exposed to light, that

in proportion as the light acts the gelatine loses its power to absorb water and gains in its power to retain a greasy ink (or oil paint). If now the gelatine film is imagined as on a thick glass plate instead of paper, and the application of the ink to be done with a roller, then by putting a sheet of paper upon the inked-up plate and pressing them together, the paper will take the ink. The inking-up and the taking of impressions on paper may be repeated, and we have a photo-mechanical method of printing. This is in essence the process known as "collotype," a most excellent method, though not so much used in this country now perhaps because the varying condition of the atmosphere with regard to its moisture affects any gelatine surface and introduces uncertainties that appear to be difficult to cope with. It will not be supposed that the preparation of a collotype plate is so simple a matter as just described. In the earliest attempts, about 1865, although the film was hardened, only some four or five dozen prints could be obtained from the plate before the surface deteriorated to a marked extent. But by degrees the adhesion of the film to the glass plate was improved and the process was perfected in other directions. It might be at first supposed that in this case there was a continuous film of ink thicker in the darker parts and thinner in the lighter. But printers' ink is practically opaque, and although a little difference in intensity in the impression can be obtained by a slight variation of pressure, it is not possible in this way to get more than an exceedingly restricted range of gradation. And besides this, the ink would not "hold" well on a perfectly smooth gelatine surface. The fact is that the surface of the gelatine in a collotype plate is not continuous, but is broken up into innumerable little cracks, reticulated as it is called, and a part of the skill in the preparation of a collotype plate is shown in getting the reticulation of a suitable fineness. A print from an example of very coarse

reticulation is given in the illustration facing page 270, and similar markings to these may be seen in any collotype print if it is examined with a magnifying glass. The coarser the reticulation is the more easy will the printing be, and a great deal too depends upon the character of the rollers and the manner of using them, for while a slow and heavy application will deposit ink, a quicker and lighter movement will remove it.

In any case a gelatine film requires to be treated with more care than a stone or zinc surface, and the greater care means slower work. In lithography, which is printing from a stone surface, the design or picture is obtained upon the stone in a greasy or waxy medium, and as the stone is slightly porous the material enters to a small extent into its surface and so becomes firmly fixed. By sponging the stone over with a solution of gum, this is slightly absorbed where the stone is bare and rejected by the greasy image. The conditions are now generally similar to those of a collotype plate; by passing an inked roller over it the image will "take" the ink while the moistened stone itself rejects it, and a sheet of paper pressed into contact will receive an impression. A finely ground zinc or aluminium sheet may be used instead of stone and the process is then called zincography or the equivalent. The drawing to be reproduced may be made directly on the stone, but more often it is made on a prepared paper and "transferred" to the stone or the zinc. So far these processes have no connection with photography, but it is possible to produce the greasy image by photographic means, and then we have photo-lithography or photo-zincography. The image may be produced directly on the stone or metal by coating it with a gelatinous material made sensitive with a bichromate, exposing to light under a negative and applying a thin coating of ink all over the surface. By washing with water and gentle friction, the

soluble parts of the film with the ink on them are removed, and the image can be got into condition for printing from. But the more usual method is to prepare a "transfer" on paper coated with gelatine or gelatine and albumen by sensitising it with a bichromate, exposing, and then applying ink to it as already described. The transfer is then laid upon the stone or metal sheet, pressed into contact with it, and the paper stripped off. There are very many variations possible at almost every stage of the process, and if the subject is other than a simple line subject, the method must be such as will cause the surface of the gelatine to reticulate in order that the gradation may be fairly represented. Photo-lithography and photo-zincography are largely used in the printing of maps, and one advantage of the latter method over the former is that the metal plates are lighter and much less bulky than the stones.

In collotype, photo-lithography, and similar processes the printing is done from a practically flat surface, and the distribution of the ink put upon it is determined by the character of the surface. It is true that there is sometimes a very slight relief, and this may be of a little assistance, but it does not constitute an essential feature in the process. There are two other main divisions of mechanical printing methods, and both of them are serviceable as photo-mechanical processes. In the first case those parts that are required to hold the ink are cut out or sunk below the surface, and in inking the plate these depressions are filled with ink while the surface of the plate is wiped clean before the paper is put upon it to make the impression; and in the other the design stands up higher than the remainder of the plate, which is cut away or otherwise lowered, and the ink is put on by a roller that touches only the projecting portions. The first is the character of a plate from which an engraving or etching is printed, while the

second is sometimes referred to as a typographic method, because the types used in the printing of ordinary books and such documents have the letters and designs upon them standing up in relief. It might be thought that Woodburytype printing came in the first category, as there the picture is sunk and in printing it is filled with the ink. But Woodburytype is a process apart, the ink is not printers' ink but a melted gelatine jelly with which the pigment is mixed, and the mould is not "inked" in the sense in which a printer inks a plate; the pigmented gelatine is simply poured upon it, so that when the paper is pressed on the top the jelly as it cools may set in the form determined by the mould. Printers' ink cannot be used in this way at all; it does not set like the melted jelly, but merely gets hard by exposure to the air as oil paint does. A thick layer of it would spread and run after the paper was removed from the mould, and even if this were prevented it might require weeks or even months to harden. On the other hand, if it were attempted to ink up a Woodburytype mould as an engraved plate is inked, the process would fail, because in wiping the ink off the surface the cloth would go into the hollow parts and remove the ink there also. In fact there is no true *surface* in this case except round the edge and in the few small parts that are to be white in the print.

It is this very matter of surface that constitutes the radical difference between the Woodburytype mould and an etched or engraved plate that can be printed from in printers' ink. The general surface of the plate must be preserved, and the lines or depressions that are to receive and hold the ink must always be narrow, and if a more extensive part of the plate is required to hold ink, the lines or depressions may be multiplied, but they must not on any account run into each other so as to make a depression of large area. In Woodburytype a thin layer of the

jelly gives a light tint, but a thin layer of printers' ink will give almost its full colour, and to get a light tint with it, the ink must be alternated with blank spaces of bare paper. However closely a Woodburytype print is examined it will be found that the tones are continuous like the tones in a painting or an ordinary photographic print, but in a print from an etched or engraved plate the tones are all "broken," the ink is in lines or dots, and it is sometimes necessary to look at the print from a little distance so that the lines or dots may merge into the interspaces and give the appearance of a continuous tint. It is possible to make the patches of ink so very small that the closest inspection will not reveal them: in such cases it only needs a magnifying glass or a low power microscope to show that they are really present.

If the subject from which the plate is to be made is a line subject, such as a drawing in pen and ink or an impression from a woodcut, the photographic production of the printing plate is simple in theory and fairly simple in practice, for in this case there are no half tones to trouble about. We will suppose that it is desired to produce a block to print with type that shall represent a diagram drawn in black lines on white cardboard. A sheet of zinc with a flat and suitable surface is coated with a thin film of albumen (white of egg) made sensitive to light by adding to it a solution of ammonium bichromate. The film is dried in the dark, pressed into close contact with a negative made from the original drawing, and then exposed for a short time to a strong light. Where the light acts upon the film the albumen is made insoluble, and it might be thought that it only remained to wash away the soluble albumen and put the plate into acid to dissolve away the surface of the exposed metal, to get the plate with the exposed lines raised on it ready for printing. This simple method would fail, because the insoluble albumen would not prove an effective protection to the zinc in the

presence of the acid. The exposed plate is therefore first coated with a greasy (printers') ink by means of a roller, then soaked in water and gently rubbed until the soluble parts of the albumen with the ink on them are washed away. We have now the lines in insoluble albumen with a thin coating of a greasy ink on them. By sprinkling finely powdered bitumen over the plate it will adhere to the greasy surface of the lines and may be dusted off the plain metal surface, and when gently warmed the bitumen will melt with the ink and afford a sufficient protection to the metal to allow of a preliminary attack with acid. But for further etching the lines need still more protection, so the washed plate is sponged over with a solution of gum, dried, and more ink is applied by the roller. The plate may now be returned to the acid that a little more of its surface may be dissolved away leaving the lines standing up in higher relief. But this action cannot be pushed far or the acid would dissolve the sides of the projecting lines of metal, and in time undercut and actually detach them. To prevent this a resinous substance is dusted on, it adheres to the greasy ink, and by gently heating the plate, it is melted and allowed to flow over onto the sides of the projecting lines of metal and protect them. By continuing these operations, the metal is gradually dissolved away where it is not protected, until the lines stand up sufficiently high to allow of the plate being printed from.

If the object or picture of which a printing block is required does not consist of simple black lines but of continuous tones of different darknesses, then a necessary preliminary to the making of the block is the translation of the even tones into an equivalent mixture of simple black and white. Suppose, for example, that there is a grey midway between black and white, we must have, instead of the continuous grey, a block that will print black lines or dots that shall collectively cover say half the space that represents the grey, so that when the print is viewed from

a suitable distance the black dots or lines and the white spaces between them will mingle and appear like the grey that is desired. If the grey is darker, the black dots or lines must be thicker or more numerous so that there is more black and less white, and if the grey is lighter they must be thinner or less numerous. In mechanical methods as distinguished from hand engraving, dots are almost always used, and as the number of them is fixed, the problem resolves itself into the getting of larger dots or smaller dots to represent the darker and the lighter tones respectively. If the dots are of a regular shape, as they increase in size they will eventually touch each other, and instead of a white surface with black dots on it, there will be a black surface with white dots. These results are simply two phases of the same effect. These effects will be easily traced in the reproductions from the photograph of a child. The second has dots that are very large that their character may be clearly seen, but even this, if looked at from a sufficient distance, will show the picture well.

There have been many methods proposed for making this translation of true half-tone into black and white. It is easy to imagine a carbon print made with a white pigment, the original being represented by a relief that is higher in proportion to the darkness of its parts. If now a kind of brush with short india-rubber taper teeth instead of bristles is coated with black ink and carefully pressed against the white print, so that the india-rubber points just touch the deepest hollows or the lowest parts of the prints, there will be formed in these lowest parts small black dots because the points of the inked india-rubber teeth will just come into contact with the surface. But in those parts that stand up in higher relief the india-rubber teeth will be flattened against the surface and form larger dots of ink, and thus the sizes of the dots will vary exactly in proportion to the height of the relief and therefore in proportion to the darkness of the part of the original represented. The

Reproduction of the Photograph of a Child with a Fine Screen

In making a printing block from a picture by photographic means, a photograph is made through a screen that is covered with small transparent spaces in an otherwise opaque ground. This gives the subject in equally distanced dots, and the light and shade are produced by the variations in the sizes of the dots.

Another Reproduction of the same Photograph with a Coarse Screen

The dots in this print are so large that they are more visible than the subject, twelve to the linear inch, while on the opposite page they are so small as to be invisible to the naked eye, there being 175 to the linear inch. By looking at this print from a sufficient distance the dots become less obtrusive, and the subject will be clearly seen.

various continuous tones have thus been translated into a simple "black and white."

The method that is used at the present almost to the exclusion of others is not quite so easy to understand as that just described and others of a similar character, although it is as effective and from a practical point of view superior. An ordinary photographic print of the object is photographed through a cross-lined screen placed just in front of the plate. The screen is covered with opaque lines ruled with mechanical regularity and in two directions, with a space between each line and the next about equal to the thickness of the lines, so that it may be regarded as an opaque screen with small transparent squares about the size of pinholes regularly disposed over it. For many years it was not clear why such a procedure as this should give the desired result, and while allowing that the action of the screen is complicated, there is little doubt now as to its primary action. At the same time that the lens gives an image of the picture on the plate through the screen, each hole in the screen gives an image of the lens or its diaphragm on the plate after the manner in which a pinhole will give an image, as we have seen in an earlier chapter. But as the apertures of the screen are large in comparison with the image of the lens that they give, the little patch of light that falls upon the plate behind each aperture in the screen is brightest at its centre and gradually fades off towards its margins. Where there is very little light, that is corresponding to the dark parts of the subject, there will only be enough light at the very centre of the patch to give an image on development, while where a brighter light from the subject falls upon the plate the developable patch or spot will be larger. Thus the translation of the tones into dots of various sizes is effected, but the dots have margins that gradually get thinner and are therefore indecisive. The dots are made "cleaner" or more precise by applying a solvent of the image to the

plate which removes the thin edges without materially affecting the denser central parts.

There are many matters that have to be taken into consideration in settling the coarseness of the screen, or in other words the number of dots in a straight line that would be included within a measured inch. For printing on a rough surface paper, such as is used for newspapers, and especially when the printing has to be rapidly done, the screen must be coarse so that the spaces between the dots may be comparatively large and stand a deep etching to prevent them from getting filled up with ink. But large dots are obtrusive and obliterate detail, and from this point of view the finer the dots the better. To get the best results from blocks made with a very fine screen the surface of the paper must be very smooth and the printing very carefully done. About sixty dots to the inch is suitable for a common paper, but a person with ordinary sight will see such dots when the print is held at the best distance for distinct vision. With one hundred and twenty to the inch the dots would be invisible unless the print were brought closer to the eye, and from this to about a hundred and fifty is commonly used for book illustrations. If very minute detail has to be reproduced the fineness may increase up to two hundred, or in exceptional cases to four hundred to the linear inch. With this last most persons would fail to see the dots even when their sight was assisted with a watchmaker's magnifying glass.

For making the printing surface from the negative taken through a cross-lined screen, a sheet of copper of the required size and with a polished surface is coated with a solution of "fish glue" containing ammonium bichromate to render it sensitive. The commonest equivalent of fish glue is "seccotine," which is well known to resemble a gum mucilage in remaining liquid when cold. The fish glue used is specially filtered to ensure a clean coating. The plate is gently warmed to dry the film, which is very

thin, and then exposed to light under the negative. After exposure it is washed that the parts not changed by light may be dissolved away, and as what remains is hardly visible, being thin and colourless, the plate is put into a dye solution which stains the image and serves to show whether it is satisfactory. If all is well the plate is then heated to a pretty high temperature, hot enough to burn wood but not sufficiently hot to char the fish glue. This changes the coating into a very hard enamel-like substance, which will not only protect the metal during the etching, but is so much more able to resist the wear of printing than the copper itself, that it may be intact after sixty thousand impressions have been taken under conditions that ten thousand impressions would notably deteriorate the block if of bare copper, and this although the film is as thin as a soap bubble just before it bursts. To etch the plate it is put into a solution of ferric chloride, that is a compound of iron with the maximum amount of chlorine, and which in the presence of copper gives up some of its chlorine to it, and the chloride of iron that remains as well as the chloride of copper that is produced can be washed away. The plate now only needs to be mounted on a suitable wooden block to be ready for the printing press, but the simple process here described is often supplemented by a little further etching of some parts or a little touching up by hand.

Those illustrations that used to be called "copper plates" or "steel plates," meaning impressions taken from copper or steel plates on which the picture was engraved, were produced by inking the plate all over, wiping the surface of the plate clean so that the ink remained only in the cut out lines and dots, and then taking the impression. These processes are now almost obsolete and their modern representative is called "photogravure." The polished copper plate for this process has to have the picture put upon it as a "resist," and it is then etched to

form the depressions that are to hold the ink. The resist is a carbon print, and that as we know consists essentially of a film of gelatine that is graduated in thickness according to the darkness of the various parts of the original. But as in this case where the most etching takes place the most ink will be held and there will be the darkest part of the impression, we want the thinnest part of the carbon print to correspond with the darkest part of the subject, and the thickest part of the print with the lightest part of the subject—that is, the carbon print must be a negative instead of as usual a positive. The common method is to prepare from the ordinary negative a carbon transparency, which is a positive, and from this to make another carbon print which will be the required negative and will be mounted on the copper plate for development. If this were done and the plate etched, the gelatine film which constitutes the carbon print acting as a resist and regulating the extent of the etching in the various parts of the plate, the image would be etched on the plate as a very shallow relief, but one which would not hold ink when the plate was wiped, for the ink would be wiped out from the shallow depressions just as it might be wiped out from the inside of a saucer. As explained in connection with the previous process the general surface of the metal must be retained, and etching restricted to very small areas of it, forming minute depressions or pits which will hold the ink. The "grain" necessary to produce this result is obtained by covering the surface of the copper plate, after it has been well polished, with minute particles of bitumen or resin, by shaking up the powdered material in a closed box, allowing it to stand for a short time that the coarser particles may settle, and then putting the plate in that the finer particles may rain down or subside upon it. By gently heating the plate, each little particle melts to a drop, and protects that portion of the surface that it covers from the subsequent etching. The

"ground" may be laid by other means, as for example by spraying a solution of the substance upon the plate, but the result obtained is much the same. Upon the plate so prepared, the carbon print already described is mounted and developed in the ordinary manner, and when dry the plate is ready for the etching. A solution of ferric chloride is generally used, and its action, which takes but a short time, can be followed by the change of colour that it produces of the metal surface. Where the gelatine film of the carbon print is thin, that is in the dark parts of the subject, the etching begins first and therefore finally produces the greatest effect, and as soon as the etching has begun where the thickest parts of the gelatine film lie, corresponding with the brightest parts of the subject, the plate is washed to stop the action, and the gelatine and bitumen are cleaned off by brushing with a solution of carbonate of soda. The plate is now ready to be printed from, unless it needs any touching up, but if many impressions are wanted it is usual to "steel face" it, by electrically depositing upon it a very thin film of the harder metal. The etching is of a very different character from that described in connection with other processes, indeed it may be more graphically described as a mere roughening of the surface of the metal. The roughening is more extensive and deeper where the etching liquid acts for the longest time, and in these parts when the plate is inked and wiped ready for taking the impression, the ink that is retained not only covers a greater proportion of the surface of the plate, but is held in greater quantity in the slightly deeper depressions. The gradation in the print depends upon both these circumstances.

It must not be supposed that all the applications of photography to mechanical printing processes have been described or even referred to in this chapter, for we have only aimed at giving the general lines upon which such applications are worked out. Each fundamental process

is subject to numerous variations to adapt it to the different conditions of the many sorts of subjects that have to be dealt with, and to the results required. For example, photogravure, which seems so essentially a hand process and more suitable for the artist himself than for the mere printer, has been adapted to rapid printing by rotary presses. The subject of photo-mechanical printing is very wide and very technical, and will be briefly referred to again in connection with the photography of colour.

As an addendum to this chapter we may perhaps refer to a matter that seems to demand reference, though only a brief reference, because while it concerns photographs it is not a photographic but an electrical subject, namely the transmission of photographs by means of telegraphy. When we say that it is possible to send a photograph of a person or of an event in ten or fifteen minutes from Paris or Manchester to London or even from a much greater distance, the importance of the achievement may be realised. It means that photographs can arrive from a distance a day earlier than if they had to be carried by messenger, and this day saved may make all the difference between success and failure, as in transmitting the portrait of a criminal or the representation of an event of importance. In 1907, the *Daily Mirror* in London, *L'Illustration* in Paris, and the *Lokal Anzeiger* in Berlin installed apparatus designed for this purpose by Professor A. Korn, and a year later one was set up in Manchester. Since then the telegraphic transmission of photographs has been a regular practice for publishing purposes, and many improvements have been effected, notably by Mr. Thorne Baker.

There is only one current of electricity passing between the transmitting and the receiving station, and all that can be done with it is to increase, diminish, stop, or start it. It is out of the question to deal with the picture as a whole, and it is necessary to "telegraph" as it were

just one small part of it at a time. To enable this to be done a suitable copy of the picture is bent upon and round a cylinder which revolves and moves very slightly longitudinally, so that a fixed point held against it would make a long spiral line that would cover practically the whole surface of the picture. By this continuous movement every part of the picture is brought in turn to the same place, and if the cylinder is of metal and the picture is prepared on a sheet of metal foil with a material that will not allow an electric current to pass, then as the cylinder revolves the current passes where the metal foil is bare, but whenever a part of the drawing comes beneath the point the current is stopped. The receiver consists of a similar cylinder covered with a sheet of paper that is so prepared that when an electric current passes through it a dark deposit is produced. The two cylinders are made to revolve at exactly the same rate, and thus all the spaces of bare metal in the drawing are represented at the distant cylinder by the deposit, and if the original is a negative, the distant reproduction is a positive. There are other ways that serve to translate the light and shadow of a picture, piecemeal, into variations of an electric current, and from the varying current to reproduce the picture, but the main principle involved is always analogous to that described.

CHAPTER XIV

THE EFFECT OF COLOUR AND ITS CONTROL

UP to this point in the consideration of our subject we have ignored colour, treating of the photography of objects as if they were all white, black, or of the various intermediate shades of grey. But one has only to look around, whether he is indoors or out-of-doors, in the town or the country, to be convinced that almost everything is coloured, and that pure blacks, whites and greys are very rare. In the house, not only the curtains, carpets and tapestries have their own colours, but the wood of the furniture and the brass of the fittings form no exception to the rule; and out-of-doors, the houses, the roads, the sea, and the sky, and almost all animals, plants and flowers, are coloured. We will endeavour to find some of the effects of colour in photography, the reasons for them, and the methods by which they can be controlled.

Assuming that the photographer employs an ordinary photographic plate and takes no precautions concerning colour, and that is the condition under which nine-tenths if not ninety-nine hundredths of the photography of the present day is carried out, he is likely to be surprised by some remarkable results. He may have become so accustomed to getting no "sky" in his negatives, that he may not notice when the blue sky and the white clouds produce the same effect upon his plate, so that the difference between them is entirely lost; but when a child's coat that is of a bold red and blue plaid shows

in the photograph as if it has no pattern at all upon it, the shortcomings of his method are forced upon his attention. Other cases might be described where the detail due to colour is lost. The reverse is also possible, for the exaggeration of the appearance of yellow freckles in the skin, which may be hardly noticeable in the person but photograph as if they were dark spots, was one of the earliest reasons that led portrait photographers to correct their negatives by working upon them with a pencil, brush, or knife. The observation of these and other discrepancies due to colour, were the cause of many leaflets of "advice to sitters" concerning the colour of the clothes that would give the most pleasing results. All such advice was, and so far as it exists still is, a confession of inability on the part of the photographer to represent certain colours as they appear to the eye. Yellows would come out too dark, some reds darker still, blues often too light, greens too dark, so that error was universal. It is true that people got used to seeing grass represented in landscape photographs as much darker than it really is to the eye, and, as the appreciation of oak and mahogany articles generally increases as the woods darken, there might be no objection to them appearing in the picture as several shades darker than they were in reality. But no one appreciated the representation of a red rose as if it were black, a buttercup as if it were a dark grey, and a violet as if it were white.

The colour of every object is due to two circumstances; first, the light that shines upon it, and second, the effect that the object has upon the light. We too often consider the second circumstance only, but a little thought will call to mind the importance of the first. The matching of colours, if they are required to appear the same by daylight, cannot be done by artificial light, and paintings made by daylight are falsified when illuminated by other means. But surely, some may say, a

red rose is always red and a buttercup is always yellow. But it is not so, and without going to the extreme of pointing out that neither is coloured in the dark, although this is true, because it might be argued that, as we cannot see anything in the dark, the red and yellow may still be there so far as we can tell, so simple an experiment as looking at the flowers by the yellow light produced by putting a little common salt in a spirit lamp flame, will show that the colour depends not only upon the object but also upon the light that shines upon it. In this light, yellow will appear to be white, while a pure red or a pure blue or a deep green will appear to be black. Those who are interested in the experiment and have no special facilities for performing it, may crush or grind some table salt as finely as possible, stir up some of it in a saucer with a little spirit of wine or methylated spirit and set fire to the mixture. An iron skewer would serve for stirring it up to get a brighter flame, and the flame may be extinguished by putting a piece of card or an old book on the top of the saucer. The altered appearance of almost any coloured article when illuminated by this flame will show that the colour depends upon the character of the light that renders the object visible.

We saw in the first chapter that ordinary light is not homogeneous, but is a mixture of many kinds of vibrations. These vibrations may be compared to the waves or ripples on a water surface, although they are not on a surface but in the bulk of the luminiferous ether, and in order to distinguish them it is usual to refer to the wave length of each, that is, the distance from the crest of one wave to the crest of the next. Sound is also a wave movement, but of a rather different kind, and takes place in the air instead of in the ether. If one note of the piano is struck, there results a sound that is generally referred to as having a constant and

single wave length, though it is not really quite so simple. But if now all the notes that are included in some three or four octaves were struck at the same time we should get a terribly discordant and complex mixture of sounds of various pitches, that is, of various wave lengths. Now white light, or ordinary daylight, is a very much more complex mixture of lights than the noise just described is of sounds. It is so very much more complex that it is impossible to suggest any figure that shall even roughly indicate how much more complex it is. Instead of about three dozen notes, each having its characteristic wave length, we have in ordinary light an inestimable number of thousands of wave lengths, so that it is impossible to attempt to picture the confusion.

There are different ways by which these may be more or less separated from one another. The simplest is by getting a thin band of light by allowing it to shine through a narrow slit, as narrow perhaps as the thickness of a sheet of paper, and then bending this band of light as one might bend a strip of paper. The bending, of course, is not done with the fingers, but by allowing the light to pass through a wedge or prism of glass. The same prism or battery of prisms bends the various constituents of light to different extents, so that instead of getting a simple line of light on the screen, the line is thickened or spread out according to the power of the apparatus until it may become a band several feet long. No one has yet spread it out to such an extent as to get a separation of the individual wave lengths of ordinary white light, but the waves of shorter length are more bent, under the same conditions, than the waves of greater length, and the proportional bending or spreading out is regular. A band of light so produced is called a spectrum, and in this way it is possible to analyse any light, artificial or natural, and compare the constituents or wave lengths of various lights.

The most complex light gives a spectrum that may from one point of view be regarded as the simplest, because it is a complete band with no breaks in it. Only a part in the middle of such a spectrum affects the human eye and is what we call in common language, light, and of this visible part the portion least bent is red, and then follow in regular order orange, yellow, green, blue, and the portion most bent is violet, as already shown in Fig. 5. Beyond the red is the "infra-red," and after the violet is the "ultra-violet," and to these the normal human eye is blind. A colour blind person is one who sees some of these colours imperfectly, and he is called colour blind because his power of vision is restricted as compared with human eyes in general. If we took the sum total of light as our standard, every one would have to be regarded as very colour blind indeed.

Considering this complete gamut of light, we may say that almost everything, like our eyes, is affected by only a part of it, or differently by different parts of it. A red object, if it is purely red, is red because it takes out of the light that shines upon it all the light that we can see except the red, and this it reflects. Whether it absorbs or reflects the infra-red or the ultra-violet would not affect the colour to our eyes, because these are invisible, and therefore our eyes cannot distinguish between their presence and their absence. In a similar way a blue object appears blue because it absorbs or quenches all the colours except the blue and reflects this. And so on with other colours, while a black object, so far as it is black, absorbs all the colours, and a white object reflects all.

A similar set of conditions apply to transparent media. A piece of colourless glass is colourless because it allows all the visible light that falls upon it to pass through it, while a red glass is red because while it allows red to

pass through it, it stops or absorbs the green and the blue. We may say of any piece of coloured glass that it is transparent to its own colour and opaque to the other colours, and when used for stopping or reducing the intensity of a part of the light, allowing the rest to pass freely through it, such a glass is called a colour filter or colour screen, because it filters out some of the light and allows the rest to pass on, and so may be compared to a sieve or screen that allows the sand to pass through it while it retains the stones.

We are now prepared to understand how the nature of the light affects the colour of the object. A red object is red because it reflects red light only, but if we cause the white light to pass through a colour filter that stops or absorbs that constituent of light that appears red, using for example a blue glass, then the object that is red in white light will appear black in this light, because it cannot reflect any other colour than red and here there is no red for it to reflect. But if we use a red light filter, then the red object will appear like a white object, because both the red and the white object can reflect the red light that falls upon them, and the white can reflect no more than the red, because the other constituents of the light have been removed. Thus it is possible to make any simple colour appear either black or white to the eye if we have the opportunity of regulating the light that falls upon it, and the light can be controlled if suitable light filters are available. And this control can be extended in an exactly similar way to photography. A buttercup, for example, in front of a black and white screen, can be photographed so that the flower appears white by using a yellow light filter, and it can then be photographed so that it appears black by using a light filter that is of a pure blue, the light filter in each case being conveniently fixed to the lens so that only the light of the required colour passes into the camera to

act upon the plate. It is perhaps obvious that if it is possible to get a light filter to remove practically all of a certain kind of light that is not wanted, that by regulating the intensity of the colour of the filter it is possible to remove any desired proportion of any part of the light that may produce too much effect. In this way the photographer may have a complete control over the character of the light that he allows to act upon the plate.

We have referred above to the spectrum as a complete gamut of light, and to the fact that only the central part of it affects the eye and produces the sensation that we call light. It is not the same part of it that is most active in affecting a photographic plate so that the silver salt that it contains is changed into the developable condition. And indeed, however many different sensitive substances that we might experiment upon, we shall probably not find two of them exactly alike in their proportion of sensitiveness to the different parts of the spectrum. We may say as a rough approximation that the notable sensitiveness of an ordinary photographic plate begins in about the middle of the region of the spectrum that affects the eye, and extends considerably past the blue and violet. Yellow and red, which are fairly bright to the eye, are dark, that is almost like black, to the photographic plate, for it is practically unaffected by them.

It has been said that therefore the photographic plate is colour blind. Both the words "colour" and "blind" are inapplicable to a plate, for it cannot appreciate colour nor can it see, but if the term is to be used in the sense in which it is here intended, we may truly say that the plate is no more colour blind than the eye, indeed less so, for if to the plate red and yellow are dark, to the eye the violet is dark and the large extent of the ultra-violet black, and here the photographic plate is very considerably sensitive. The simple fact is that the eye and the plate are differently sensitive.

We judge of colours by our eyes, and we want pictures

to represent them as nearly as possible as we see them. To the eye yellow and yellowish green are the brightest colours and red is rather less bright, but they are almost like black to the plate, while blue, which produces almost as much effect as white upon the plate, is to the eye darker than either red, yellow, or green. It is this difference of sensitiveness that accounts for all the discrepancy that colour causes between what we see and what we get in a photograph. Now an ordinary gelatino-bromide plate is not altogether insensitive to green, yellow, and red, but its sensitiveness to these colours is so small that it is quite inappreciable under ordinary circumstances. If we use a deep orange colour filter, one that will stop or filter out about nine hundred and ninety-nine thousandths of the violet and blue light and altogether stop the ultra-violet, then we give red, yellow, and green a chance to produce an effect upon the plate, because the period of the exposure can be increased to nearly a thousand times without the blue and violet producing too much effect. By thus handicapping the light that is excessively active, it is possible to get all coloured objects represented in a photograph with very much the same relative brilliancy that they appear to have. This increase of exposure to about a thousand times is quite possible with some subjects, especially if brilliant out-of-door daylight is available, as it is in some countries where the weather is more reliable than it is in England. But in the great majority of cases such an increase in the period of the exposure is quite out of the question, and hence the increasing of the sensitiveness of the plate to green, yellow and red, becomes a matter of the first importance.

Professor Hermann Vogel of Berlin, in 1873, found that some plates were abnormally sensitive to green light, and was thus led to try the experiment of adding dyes to the sensitive salt, hoping that a dye that would absorb green, yellow, or red light would increase the sensitiveness

of the plate to the colour that it retained. His hopes were realised, and he prepared plates sensitive to green light and others sensitive to red according to the dye that he employed. He found, however, that the sensitiveness of the plate to blue was still proportionately too great, and so he put a yellow glass in front of his lens to reduce the power or intensity of the blue. In these experiments Dr. Vogel laid the foundation of what is called isochromatic or orthochromatic photography, but as the modern gelatine plate was not known at that time, it was not until rather more than ten years after this that isochromatic or orthochromatic plates as we now know them were introduced.

An "orthochromatic" or "isochromatic" plate is, strictly speaking, one that will render coloured objects so that in the print they appear as proportionately bright or dark as they appear to the eye, irrespective of their colour. But as these terms were used to describe the first commercial plates that constituted a step in this direction, their meaning has been restricted ever since to plates that have an enhanced sensitiveness to green light, red light remaining almost without action upon them. If the plate is of notable sensitiveness to red as well as to green it is called "panchromatic." There is no plate that will of itself render various shades of blue, green, and red correctly, because the sensitiveness to blue always remains largely in excess. If the action of the blue is reduced by means of a yellow filter, as already explained, it is possible to get blues and greens, almost without exception, represented as desired by using an orthochromatic plate, but yellows are only partially corrected, that is they come out too dark, while reds are scarcely at all improved. By using a darker colour filter it is possible to get blue and yellow relatively correct, but such a filter will over-correct for the green, making it appear too light.

The Effect of Colour and its Control

When orthochromatic plates were first introduced, designs consisting of various combinations of blue and yellow, sometimes with white and black included, were offered as subjects to try them on. Messrs. B. J. Edwards & Co., who were the first makers of orthochromatic plates in England, printed a bright yellow disc, with the letters "XL" on it in very dark blue, and "trade mark" in white. The yellow was so light that the white "trade mark" was hardly noticeable until searched for, and the blue was almost black, so that what appeared to the casual observer was a practically black "XL" on a light yellow ground. But a photograph on an ordinary plate showed "trade mark" as if it were printed in white on a dark ground, and the "XL" did not appear, for the dark blue and the yellow were so balanced that they produced the same effect in the plate. This experiment was very striking, for the original and the photograph appeared to be quite dissimilar. By means of an orthochromatic plate and a suitable yellow light filter, the blue could be photographed as if it were black and the yellow as if it were white, or with any intermediate effect. By using only these two colours the advantage of the plates was demonstrated without their shortcomings being manifest, for if a good yellowish green or red or both of these had been added, then the limits of their power for colour correction would have been obvious. If by the use of a suitable colour filter the blue and the yellow had been obtained according to their respective darkness, the red would have shown almost as if it were black and the green would have been represented as brighter than it really was, because of the deficiency of sensitiveness in the plate to red. But, whatever their imperfections, these plates are a very great improvement on ordinary plates, when coloured subjects have to be dealt with.

It was demonstrated by Vogel in his earliest experiments that it was possible to increase the sensitiveness

of a plate to red by the use of a suitable dye, but the difficulties and the risks that have to be incurred in such sensitising on a manufacturing scale prevented the preparation of red sensitive plates for many years, and those who needed them prepared a few at a time for their own use. But eventually red sensitised plates were put upon the market, notably by Messrs. Lumière and Messrs. Cadett, and during the last few years a further step has been taken in the preparation of plates sensitive to all colours (panchromatic plates) in as even a way as possible. At the same time the manufacture of colour filters has been perfected, and Messrs. Wratten & Wainwright have specialised in this matter to such an extent that they issue a catalogue of nearly eighty different filters. By the joint use of colour sensitised plates and colour filters, the photographer has at the present day almost everything that he can desire in the power to control the effect of colour in his work.

It is not unusual to speak of plates that have been colour sensitised, whether by adding the dye to the emulsion or by putting the coated plate into the dye solution, as "dyed plates." This description seems perhaps particularly suitable when the plate itself is immersed in the solution of the dye, because of the similarity of the operation to the process of dyeing fabrics, but it is liable to lead to a misunderstanding. It appears to be definitely proved that all dyes are not serviceable for this purpose, and that the dye only becomes effective by forming a compound with the sensitive silver salt, and that the excess of the dye that does not combine in this way remains soluble and is advantageously washed away. Thus it is the new compound produced that gives the new sensitiveness, and there is no need for the somewhat fanciful theories that the dye absorbs the light of that colour to which sensitiveness is desired, and holding it as it were in bondage obliges it to act against its disposition

upon the silver salt; nor on the other hand that the light acts upon the dye alone and so changes it that the products of its change affect the silver salt.

It might be thought that in ordinary photography, where it is desired to get a picture that will represent the object photographed as nearly as possible as we see it, that the soundest advice would be always to use panchromatic plates in conjunction with a light filter that will exactly compensate for their excessive sensitiveness to blue and violet and the ultra-violet. In one sense such advice is safe and good, and if a person were fearful of being involved in a railway accident, it would in a similar sense be safe and good advice to urge them never to travel in a railway train. But a policy of total abstinence is always unreasonable, except when it has to do with something that is invariably an evil. Other things being equal, ordinary plates are cheaper, more stable, and require fewer precautions in their manipulation than colour sensitised plates. When a colour screen is used the exposure must always be prolonged, and without a colour screen a colour sensitised plate shows very little improvement. It is obviously not worth while to incur the disadvantages associated with specially sensitised plates unless there is something to be gained by their use. When and when not to use them becomes therefore a very practical question. In a general sense colour demands the most careful consideration when a very obvious colour or many colours have to be dealt with, as in pictures, dyed fabrics, and flowers. Houses built with yellow or red bricks and slate roofs appear to the eye to have the roof much darker than the walls; when photographed with an ordinary plate the probability is that there will appear only a little difference between the walls and the roof or that the roof will appear to be the lighter. Yellow or reddish sand, the greens of foliage and grass, and golden or auburn

hair, will come out too dark if an ordinary plate is used. The grain of coloured woods such as mahogany and oak is likely to be almost lost unless special precautions are taken, and the cracks in old oil paintings will often be very much emphasised under the same conditions. But on the other hand, a black and white object such as a drawing in Indian ink, an engraving or a print, a marble or a bronze statue, a stone building, and many other such objects, do not call for any precautions as to colour, and where the photograph is made simply to record a position, such as of a movable index or scale, then colour may be absolutely disregarded.

There is one other case that is not generally associated with colour but which really belongs to the same class of phenomena, and that is the mistiness that almost always affects our view of objects at a distance. This is due to the particles in the air, the presence of which is demonstrated by the motes that may always be seen dancing in a sunbeam. The nature of the light that these reflect or scatter depends upon their size. If they are small enough they scatter or reflect only the ultra-violet light, and as this is invisible the scattering of it makes no difference to the appearance of things. But if these particles are larger, then they affect the light that we can see, and as every particle is illuminated just like the things that we see the shape of and handle, the air appears to be full of light, and we call the appearance a mist if we are in it and it is general, or a cloud if we are not in it and its limits are more or less obvious. We get the same effect, but in an exaggerated degree, when a passing motor car stirs up the dust, but the particles in this case are larger still and often in greater quantity. Now it seems that there are always small particles in the air, and that often though not always there are larger particles also the effect of which is plainly visible. But the photographic plate is sensitive

to the ultra-violet, and to this extent is affected not only by the mistiness that we can see, but also by the more universally present mistiness due to the ultra-violet and dark blue light which is scattered by the smaller particles and not recognisable by our eyes. Hence it generally happens, unless special precautions are taken, that the mistiness due to distance is very much exaggerated in a photograph. The cure for this is obvious; we have only to prevent the ultra-violet and the dark blue light which constitute the mist from reaching the plate, and this is done by putting on the lens a colour filter that will absorb it.

It follows almost as a matter of necessity, that if one has the power to control the effects of variously coloured lights and so to bring the result into harmony with the impression of the scene that our eyes receive, that it is possible to overstep the mark and produce discrepancies in the opposite direction. We can by "over-correction" make our yellows, greens, and reds come out too light and our blues too dark. This is a possibility, though not a probability, if we may judge by general results. But this very power is sometimes of the greatest service. Engineers' drawings are often copied by the ferro-prussiate process, which gives a blue image. The blue colour of the print has no significance; it is accepted merely because the process is cheap and easy to work. The blue image and white paper give only a feeble result when such a print is photographed in the ordinary way, but by causing the blue to photograph as if it were black a much superior result can be obtained. In the study of cloud forms it may be desirable to render the blue sky as if it were black and so to emphasise the clouds. Biological preparations are often stained with a colouring matter that will affect some parts of them and not others, in order to bring into greater prominence the important details. The colour is used solely

for this purpose, and it is a matter of indifference whether it is red, blue, green, purple, or what it is, so long as it makes the detail more clear. It is easy in photographing such a preparation to intensify the action of the stain and make the stained details appear in the photograph as if they were very much more conspicuous than they really are. And we might mention other cases where this possibility of exaggerating the effect of colour is of the greatest importance.

It is obvious that it is possible to go still further in this direction than has been indicated, and take photographs by "light" that the eye cannot see, because in the spectrum it lies outside the range of vision beyond the red or beyond the violet. Professor R. W. Wood has taken many photographs with such "dark light," and by his kind permission we are able to show (facing this page) a landscape taken by means of infra-red light. It will be noticed that the picture is quite different from what we see. The blue sky is very dark, the green foliage and grass appear as if they were very bright—so bright, indeed, that they look as if they were covered with snow. The shadows are unduly black, sometimes of a coaly blackness, because the particles in the air, though they scatter blue light, are generally too small to affect the red, much less the infra-red. If ultra-violet light is used, window glass becomes opaque, Chinese white becomes black, printers' ink appears as if it were lighter than we are accustomed to regard it, and shadows almost disappear although the sun may be shining, because the air is so misty to the ultra-violet light that it diffuses it as a fog does. We see therefore how the appearance of things in general depends upon the sensitiveness of our eyes to the various constituents of light, and that if we had a larger range of vision, or were less "colour blind," it would not be an unmitigated advantage.

R. W. Wood

PHOTOGRAPHED BY INFRA-RED LIGHT

Infra-red light is light of wave-lengths too long for the eye to be affected by it—to the eye, therefore, it is not light at all. The usual discrepancy that exists between a view as we see it and as it appears in a photograph when an ordinary plate is used is due to the light being of wave-lengths *shorter* than those that chiefly affect the eye. This difference therefore is here reversed and very much emphasised. The sky is very dark, the shadows are practically black, and the foliage and grass are so light as to suggest that they might have been covered with snow.

There is another matter closely connected with this subject, though it has exactly opposite aims, namely, the selection of a suitable means for the illumination of the dark-room, the room in which sensitive materials may be unpacked, put into the camera, developed, and indeed manufactured. We want for this purpose a light that shall be as bright as possible to the eye and as weak as possible in its action on the plates or papers. The selected light is obtained by causing the source of illumination to shine through a coloured medium. Now no colour filter can be absolute in its action. If, for example, it stops or absorbs the blue constituent of any ordinary light, and it is of such an intensity that it absorbs nine-tenths of the blue, allowing one-tenth to pass, if a second layer of the same medium is put against the first, it also will absorb nine-tenths of the blue that falls upon it and transmit one-tenth. If therefore one layer allows only one-tenth of the blue to pass through it, two layers will allow only one-tenth of one-tenth—that is, one-hundredth—to pass, and a third layer would allow only one-tenth of this hundredth to pass through, and so on. Thus there is no absolute effect, and a light that would produce no effect upon a certain plate at a certain distance when exposed to it for a certain time, might spoil the plate if the distance were reduced or the time increased or if the plate were a little more sensitive. There is no such thing as an absolutely safe or inactive light. A dark-room lantern may give a practically safe light with a candle and an unsafe light with a paraffin lamp or gas flame; it may be safe at a distance of a yard, but very unsafe only a foot away. It is therefore essential to have a constant light or one that can be regulated, and this means that daylight must be given up altogether, except in the case of materials that are only slightly sensitive. If a window were covered over with a coloured medium and the light passing

through rendered practically safe in the winter, it would fog the plates in the summer, it might be safe on a dull day and quite unsafe a day or two afterwards when the weather happened to be bright, and if the coloured medium were dark enough to make the light suitable in bright weather, on a dull day the amount of light would be so small as to be scarcely worth having.

The first step in preparing a useful light for the dark-room is to remove or absorb the ultra-violet, as this affects the plate and is of no use whatever to see by. The next step is to absorb the blue, as this has a considerable effect on the plate and is dark to the eye. Blue is removed by a yellow screen or filter, and a yellow light has the advantage of being the brightest light to the eye and having only a slight effect on ordinary plates. For plates that are specially sensitised for green, this colour should be removed as well as the blue, and this leaves us with a red light. With panchromatic plates the only safe way is to have no light at all, or if there is a feeble light, to so manage that the plate is always shielded from it. If a plate were equally sensitive to all colours and a light was necessary for its manipulation, a yellowish green light would be the best, because this is the brightest to the eye, but it would have to be reduced in intensity until its action on the plate was negligible when exposed to it for the required time. Such a light would be very feeble indeed.

CHAPTER XV

THE PHOTOGRAPHY OF COLOUR

PHOTOGRAPHY is essentially a monochromatic or "black and white" method of pictorial representation. As shown in the last chapter, it is affected by colour because the character of the activity of light depends upon its wavelength, as also does its colour. Photographs may be made of, practically speaking, any colour, not only of those purplish and reddish browns that used to be associated with the expression "photographic," but of almost any pigment or dye, using such methods as the carbon process of printing or photo-mechanical processes. But the reproduction of colour by photographic means is an entirely different matter, for to do this we must have several colours on the same photograph, and the placing of these colours must be effected by the action of light. Clearly, too, we must not only get striking and decided colours, but all the various tones and tints of them, and also black and white at the same time. It would be useless to be able to imitate the tint of a man's face, if the black of his coat and the white of his collar could not be reproduced. And it is in this that the best test of any method of colour reproduction depends. It shows a crudeness of idea and a want of appreciation of the difficulties of any method when strikingly coloured objects are selected as tests, a red-coated soldier rather than a civilian, or a bunch of flowers rather than a sober landscape. The exhibition of the photographs of such objects may always be taken to indicate that the process illustrated is in its early stages,

and cannot be trusted to give those delicate differences of shade that constitute the true beauty of all colour.

It is easy to superficially describe what is meant by the expression "a photograph in colour." In the production of a Daguerreotype, the form of the object is accurately rendered, or if the apparatus is defective the error can be discovered and definitely expressed, and the light and shade (irrespective of colour) is also given accurately or with deviations from truth that are subject to absolute laws. The common idea of a photograph in natural colours is that the colour of the object shall be reproduced with the same certainty as its form and brightness. We often hear people who know nothing whatever about it, say that they do not see why it should not be so, and they will prophesy that such a result will certainly be achieved. But no one who speaks so can give any reason why it should be so, or offer any justification for his prophecy. There seems to be but the feeblest shadow of a foundation for the hope that such a method of colour photography will ever be realised.

We may call this the *direct* method of colour photography, for it has been the dream of a section of photographic experimentalists for generations, and a certain measure of success has attended their efforts. The success may be compared to the Will-o'-the-wisp that lures the traveller onwards without helping him home. A little more than a hundred years ago, Dr. T. J. Seebeck of Jena noticed in photographing the spectrum on silver chloride that violet light sometimes produced a violetish reddish brown, blue sometimes produced a blue, and red a rose or lilac coloured substance. These results were recalled and confirmed when photography became a practical art because of the introduction of the Daguerreotype, and Edmund Becquerel in particular produced layers of chloride of silver in various ways, and actually succeeded in getting in his photographs the colours of brightly dressed dolls,

and coloured designs. But Robert Hunt, another experimentalist, records how he once obtained what he calls a very beautiful picture, in which the sky was crimson, stucco-fronted houses slaty blue, and the green fields a brick red. The colours obtained by these methods were not permanent; by carefully preserving the photograph in the dark they might last for a few years, and they were destroyed by any attempt to fix them.

There is no doubt that under certain conditions light, when it acts upon some substances that it can change, tends to produce a substance that will reflect light of the same colour as that which induced the change, and in 1868, Dr. W. Zenker of Berlin, published a small volume in which he sought for an explanation of this tendency. He pointed out that this result is specially noticeable in Becquerel's method, in which the sensitive layer of silver chloride is produced on a silver plate, and suggested that the cause of the colour was the production of metallic silver, which of course is itself not coloured, in layers in the film, something like the leaves of a book with just a little space between each leaf and the next, the width of this space depending on the colour of the light that produces the decomposition of the silver salt.

In the first chapter of this volume, we endeavoured to indicate the general character of light by an experiment. A piece of cord was fastened to a hook, and the free end given a jerk that caused a raised portion or hump to travel along the cord. If the cord were long enough the hump would be seen travelling from the hand to the hook—but more, it would then come back again, being reflected at the fixed end of the cord. If now instead of one jerk producing one hump, a rapid succession of jerks is maintained, a row of humps will travel along the cord, and every hump when it gets to the fixed end of the cord will come back again, and thus there will a row of humps going in both directions. The humps that are going and

the humps that are returning must affect each other; they must interfere with each other, because the cord cannot move in two directions at the same time. The final effect of the succession of humps travelling along the cord in both directions may be seen with a little care—and it is that there are produced a number of humps that do not travel at all. Each hump keeps moving across the line of the cord, first above and then below if the jerk given is up and down, so that the effect of the jerk given by the hand continues to pass along the cord, for there is nothing else that causes it to move, but the humps themselves do not travel. Exactly the same effect is produced when light of any single wave-length is reflected back along its own path, and the waves that are produced are called "standing waves" or "stationary waves" to distinguish them from travelling waves. When a result such as this takes place in a sensitive film, the sensitive substance will be acted on to the greatest extent where the movement of the luminiferous ether is greatest—that is, at the crests of the waves—but between the waves, at the nodes, where there is no movement, there will be no action, and therefore the product of the change will be disposed in layers as described. Zenker pointed out that such layers might be expected to reflect most strongly light of the same wave-length as that which produced them, and therefore to pick out light of this wave-length or colour from white light and reflect it.

Professor O. Wiener of Aachen, rather more than five-and-twenty years ago, investigated the character of the colours produced by the direct methods of colour photography, and he found that the colours produced by Seebeck's method were of the nature of pigments, and did not give their colour by the action of layers that would result from the action of stationary waves, but that when a silver plate was used as in Becquerel's method the case was different and the colour behaved as if it

had origin in such a manner. Professor Lippmann of Paris, in 1891, perfected this method of Becquerel's in the light of the suggested principle upon which it was founded, and so elaborated his method of colour photography.

For the practice of Lippmann's method, the essentials are a film that contains an exceedingly fine deposit of the silver salt, for a coarse deposit would clearly interfere with the integrity of the layers that are so close and thin: the silver compound must be sensitive to all colours, so that every colour may produce its due effect; it must be transparent, so that the standing waves may be produced in it without impeding conditions; and there must be a good reflector close against the film, to send the light back upon itself. He prepared a film on glass having these characteristics, and for a reflector used mercury. The plate carrier was so constructed that when the plate was fixed in it with its glass side towards the lens, clean mercury could be poured in until the film side was covered with it. After the exposure the mercury was run out, and the plate removed and developed. That there really are these layers of silver produced in the film by the standing waves has been abundantly proved by several investigators who have cut sections of the films and magnified them. As the colours shown by these photographs depend upon the distance apart of these layers, any circumstance that affects this distance must change the colours. When the film is wetted the gelatine swells and the layers are more separated. The colours therefore do not show while the plate is being developed, but only after it is dry. By merely breathing on an unprotected film its expansion is sufficient to cause the colours to change if they do not vanish, and to secure the plates against such changes it is usual to cement a glass plate on to the surface of the film. To see the colours of these photographs, the light must fall upon them in a

convenient direction, so that the reflected light may pass to the observer's eye. It would be useless, for example, to hang them on the wall as pictures, for the colours are only visible under the definite conditions described. They can only be made of dimensions that are quite small compared with the focal length of the lens used, presumably because the rays that fall upon the margins of the plate, if too oblique, would, after reflection, not travel back upon their original paths. With all these limitations and the difficulties of the method, this process of colour photography is a curious experiment or an interesting demonstration of the existence of standing waves rather than a practical process of colour photography, and it seems likely to remain so. We may regard this as the final result of the attempts to discover a direct method of colour photography.

The indirect principle of colour photography comprises all the practical methods at present available, and it differs from the direct methods in that it is not sought by photographic means to produce colour or any disposition of silver in the film that will cause colour by certain arrangements of light and inspection, but merely to photographically regulate the disposition of pigmentary or colouring matter. This is an entirely different problem from the other, and one that has been solved in many ways. Indeed we may say that the only bar to perfect success is the difficulty of getting the pigments or the dyes of exactly the right colours and in exactly the right proportions, and the difficulties of manipulation that must be always present when several operations are necessary to produce the desired result.

There are certain facts that have led to the supposition that the ordinary human eye appreciates colours by means of three different kinds of sensitive points, or whatever they may be called, which are intermingled on the retina, one kind affected by red light, one by green, and the other

by a blue that inclines towards violet. It is found that it is possible by means of these three colours to imitate any colour so closely that the eye cannot distinguish between the original colour and the imitation. It is important to notice that this is not a question of mixing pigments or paints, but of mixing lights, for if this difference is not borne in mind the subject cannot be understood. A red light may be obtained by putting a red glass in front of a lantern and a green light by the use of a green glass, as we see every day in railway signalling. The fundamental fact is simply this, that if we had three lanterns, one giving red, one green, and one a violetish blue, and if these colours were properly selected, then by allowing them all to shine at the same time and with a suitable intensity upon a surface as of white paper, the surface would appear white where the lights were superimposed. By altering the intensity of any one, the balance would be upset, and the paper would appear coloured, and by suitably regulating the intensity of them, or by the use of any two of them or any one of them, all colours can be imitated. Although the eye cannot distinguish between the original colour and its imitation, they may not be the same, and this can be proved by the separation of each into its constituents by getting the spectrum of it. In this imitation we take advantage of the limited power of the eye to discriminate in the matter of colour. Whether or not we actually see colours by the means of three different kinds of sensitive points in the eye, does not affect the fundamental fact that all colours can be imitated by the use of a certain three; the "three-colour" processes of colour reproduction therefore do not depend upon any physiological theory as to colour vision, but only on the experimental facts that have led to such theories.

All three-colour processes consist in photographing separately the redness, the greenness, and the blueness of the object, and then by some means and the use of suitable

pigments or dyes getting the redness, the greenness, and the blueness together. There is then a photograph of the object with all the accuracy of an ordinary photograph and in its natural colours, or rather colours which no human eye can distinguish from them. It is obvious in a moment that the success depends upon many details. The photograph of each colour, red, green, and blue, is obtained by photographing the object through filters or coloured screens of these colours. For getting the final result the three suitable pigments or dyes have to be found, and each of them must be correctly proportioned to the others, for otherwise whichever was in excess would give a predominating tint over the whole picture. Absolute success is therefore impossible ; it is only a matter of degree, and as a matter of fact three-colour prints may be met with in commerce varying from those that are so perfect that it is not possible by inspection to find a fault in them, to those that are mere travesties of the process—three-colour prints certainly, but not even an approximation to the imitation of the original. Chromo-lithography in which any number of separate colour impressions up to twelve or fourteen or more might be necessary to produce each print, is now practically obsolete, for the colours are more correctly rendered by the use of three only, provided that these are properly selected. This is an example of the commercial value of scientific work that was carried out at first without any thought of its practical applications.

All three-colour photography, and all useful methods of colour photography are included in this description, are of the general nature described above. We have no wish to attempt here to apportion to each one of the innumerable workers in this field—some working theoretically and scientifically, and others practically and empirically—their share in the development of the various methods by which this process may be worked. When a name is mentioned

it is because it has become associated with a specific procedure which it serves to identify. But we may say that three-colour photography was known theoretically before it was possible, for practical methods of photographing reds and greens may be regarded as dating from 1873, when Vogel discovered the possibility of sensitising plates for these colours. It was not until about 1890 that colour photography began to be of commercial interest.

There are two distinct methods by which the principles of three-colour photography may be applied to get a practical result, and these are distinguished as the "additive" and the "subtractive" methods respectively. The names are self-explanatory; in an additive process the colour constituents are added, while in a subtractive process the final result is obtained by subtracting or withdrawing the colours that are not wanted. It is necessary to get a very clear conception of the general principles involved in these two main divisions of the various processes before the details of any one particular process can be appreciated. In our endeavour to make these clear, we will use the simple words red, green, and blue to indicate that particular red, green, and violetish blue which correspond to the three primary colours from the physiological aspect of colour vision.

If any object is photographed with a suitable red filter or screen on the lens so that only red light can pass into the camera, then only the redness of the object will be photographed, other colours will be excluded by the colour filter. This redness will include not only the colour of those parts that appear red but also of those parts of any colour of which red is a constituent, that is, any colour which, when illuminated by white light, reflects red either alone or mixed with other colours. A yellow object is yellow because it reflects red and green lights, a purple object reflects red and blue, a white object red, green, and blue; and brown and other more complex

shades, as well as all colours that are light in tint by being mixed with white, reflect some red, and the red constituent of all these will be photographed according to its intensity under the conditions described. The negative that is obtained will have a deposit of silver corresponding in density to the brightness of the redness, or the red constituent of mixed colours. If a print on glass is made from this negative, the redness of the original will be represented by transparent parts, where there is less redness there will be a grey deposit; and where there is no redness there will be an opaque deposit, so that if a red glass is put in contact with this print or transparency and the two are held up to the light, there will be seen a true representation of the redness of the object. Such a photograph is a record of the redness. The greenness and the blueness of the object may be photographed in exactly the same way by putting a green or blue colour filter in front of the lens so that only the required colour can enter the camera. Prints on glass or transparencies may be prepared from these negatives, and by putting in contact with each colour record a glass or film of its proper colour, we have a complete representation of the object in three parts, according to its colour, its redness, its greenness, and its blueness. If the light that comes through these three photographs, each with its proper colour filter, can be united, then so far as our colours have been correct and our work free from error, there will result a picture of the original with all its colours and shades of colours correctly represented. They must not be put one over the other, because each must have a full and equal light, and if they were superposed the second would only get the light that had passed through the first, and the third the small remainder that had been able to pass through the other two. If each of these photographs with its colour screen attached is put into a separate optical (or "magic") lantern, we can set three separate pictures on the screen—that is, the redness, the

greenness, and blueness of the original. If now these three pictures are brought together so that each one falls upon exactly the same place of the screen, then the three colour images are truly added, and there results a vivid picture of the original in its true colours. This is an excellent method of colour photography and gives splendid results, but from the apparatus required it is obviously a method for the lecture theatre only. It is a simple "additive" method. Some years ago Mr. F. E. Ives perfected and put on the market his "chromoscope," a small table instrument in which by an arrangement of reflectors the light passing separately through each of the transparencies with its appropriate colour screen was caused to combine in the eye of the observer, and when the whole apparatus was doubled so that stereoscopic photographs were taken and observed, the result was as realistic as it is possible to imagine.

The simple method just described, simple in its theory and in the directness of its method, though not simple from a practical or commercial point of view, leaves nothing to be desired so far as its results are concerned. But to have three separate photographs and the need of an instrument to unite them is cumbersome and costly. The possibility of doing the whole thing on one plate was understood more than forty years ago. It is only necessary to divide the surface of the plate into minute patches, too small to be individually recognisable at the ordinary distance of vision, and to colour these patches red, green, and blue alternately, to get the colour elements all over the plate. Such a plate will appear to be grey, because although the light that passes through the little colour patches when mixed produces white, the maximum total of light that can pass through is one-third of what would pass if the colours were removed. If such a plate is coated with a suitable photographic emulsion and exposed in the camera so that the light that falls upon it passes through the three-colour

screen before coming to the emulsion, then if the object is, for example, red, the red light will pass through the little red patches and produce, on development, an opaque deposit of silver behind each red patch. The red light cannot pass through the green and blue patches, and therefore produces no effect behind them. If the developed plate were fixed in the ordinary way, we should get exactly the reverse of what we want, so far as colour is concerned, for the red that we want would be stopped by the opaque deposit behind it, and the green and blue that we do not want would be left with nothing to hinder the light passing through them. But if instead of dissolving away the unchanged silver salt as in ordinary fixing, we dissolve away the image of metallic silver, which can be easily done by suitable means, and the silver salt that remains is then exposed to light and developed so as to get an opaque deposit, then on holding up the plate to the light we shall see red only, wherever red light fell upon the plate when it was exposed in the camera. In an exactly similar way the other colours, whether simple or mixed, will be reproduced. By this dissolving away of the silver image instead of the ordinary fixing, what would have been a negative is made into a positive, which, as was explained in detail in the previous case, is what is required. Such a process is called a "screen-plate process" to indicate that the screen and the plate are in one.

The difficulty of working out a practical process on the lines just described was to get these minute patches of the three colours, and several of the methods that were successful experimentally, failed when attempts were made to work them on a commercial scale. The early experimenters put the colours on in alternating lines, ruling them in coloured inks or paints. But it was impossible to rule lines of the fineness necessary with no spaces

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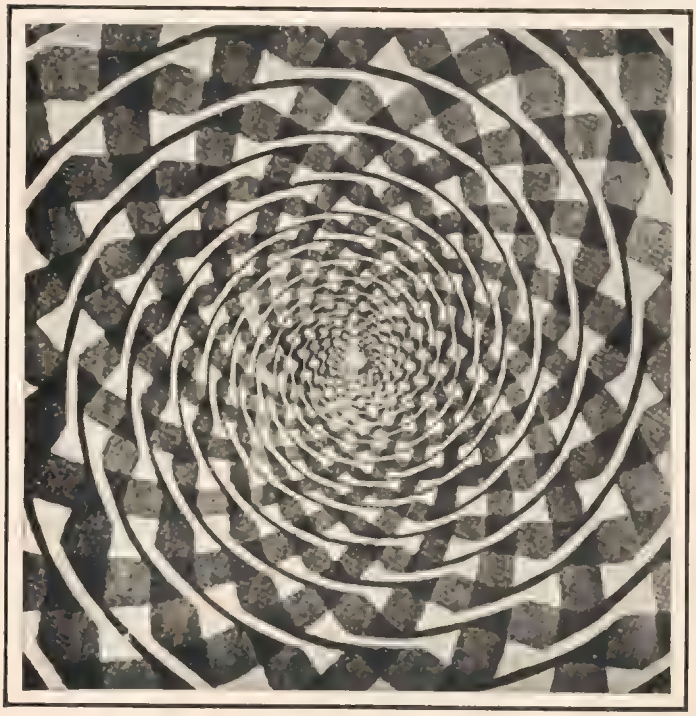

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Optical Illusions

These illustrations show that the unassisted eye may be deceived, even in spite of a careful and prolonged inspection of a design. It is difficult to believe that the letters L I F E are upright, and that the lower illustration consists of concentric circles.

between them and no overlapping. The first successful method was perfected by Messrs. Lumière of Lyons when they issued their autochrome plates in 1907. Most starches consist of minute rounded granules, each complete in itself, and which when heated in water will burst. In the preparation of autochrome plates Messrs. Lumière take starch of a suitably sized granule and dye it in separate batches red, green, and blue, and dry it with suitable care that the granules may remain perfect. These dyed granules are then mixed in such proportions that neither of the colours predominates, and the mixture is spread upon a glass plate that has a sticky coat of varnish upon it. The granules adhere, and when the plate is completely covered and the excess removed it is pressed to flatten out the round granules and fill up the minute spaces that may be left between them. The filling up of the interspaces may be done more completely by the application of a fine black pigment which will adhere only where the sticky coat of varnish is uncovered. A layer of a waterproof varnish is applied, and on this the panchromatic photographic emulsion is coated. One disadvantage of the use of starch granules is that they are not very transparent, and so cause a further loss of the light, which has already, by the colours themselves, been reduced to one-third or less. Since the autochrome plates were introduced, three or four other firms have started the manufacture of similar colour plates, but using coloured inks or dyed gelatine instead of starch granules, and arranging the colours in regular order instead of at random. The "Thames" plates had two colours as round dots and the third filling up the interspaces. The "omnicolore" plates have alternating narrow and rather wider lines. The narrow lines are of one colour, and the wider lines consist of alternating squares

of the other two colours. Clearly many other arrangements of the colours are possible; it is only a matter of convenience.

By the use of these screen colour plates many excellent results have been obtained, but the getting of colours that match those of the original is not by any means ensured by blindly following the instructions supplied for their use. There is one notable fact in connection with them, namely, that the proportional intensities of the three colours is fixed by the maker. This is an advantage to the unskilful worker, because he has so much less opportunity for making mistakes. But the opportunity for error is not eliminated, though the adjustment of the colours in the first case is done by those who are accustomed to the work, and are therefore likely to be more successful than any one of little experience.

The production of transparencies by the subtractive principle in colour photography, though radically different from their production by the additive principle, is in a general sense very similar to it. The redness, greenness, and blueness are photographed exactly as before, and from each negative a print is obtained, the aim being that the three prints when suitably coloured shall be superposed so as to make one single print or transparency. This method was suggested long ago, and the simplest way of carrying it into effect was applied by Mr. Ives, but it is generally associated with the name of Mr. Sanger Shepherd, as it is his firm that has put it on a sound practical and commercial basis, and that supplies the necessities for it. It is in the colour of the three prints that the difference lies between the additive and the subtractive methods of colour photography. When the coloured lights are added, the red, green, and blue together give white upon the screen; but if red, green, and bleu

films were superposed and held up to the light, the combined film would appear black, for each would allow only one colour to pass through it, and this would be stopped by the other two. We therefore cannot use these colours when the films are to be superposed. In the additive method the position and intensity of the colour in each case was regulated by a black image that excluded it where it was not wanted. This is clearly impossible when the films are superposed, because the second and third colours are wanted in the very places where the first is stopped by the opaque image.

These apparent difficulties are surmounted by using the complementary colours in the complementary positions. That is, instead of putting where we want red, a red dye that will allow only red to pass through it, we put everywhere else a dye that will allow the other two colours to pass. As the other two colours are green and blue, the colour used for the red plate is a greenish blue. The colour used for the green plate is a pink, which allows the red and blue to pass but not the green, and this is put everywhere except where green is wanted. And yellow, which allows red and green to pass, is used for the green plate. Suppose that there is a pure red in the object, the film that corresponds to the redness of the object is here colourless, and therefore allows red, green, and blue to pass through it. But in this very place the film that corresponds to the greenness of the object, as it allows only the red and blue to pass, stops the green, and the film that corresponds to the blueness of the object, allows only the red and green to pass and stops the blue, so that the sum of the effects of the three films in this particular part is that green and blue are absorbed and red alone gets through, the colour that corresponds with the colour of the object. This will perhaps be better understood from

the adjoining table. The blank spaces where the colour of the object and the record correspond show that there is no colour—the film is colourless and transparent. It is now clear why this method is called the subtractive

	Red Object.	Green Object.	Blue Object.	Dye Used.
Red record . .	... ...	Absorbs red	Absorbs red	Bluish green
Green record .	Absorbs green	... ...	Absorbs green	Pink
Blue record . .	Absorbs blue	Absorbs blue	... ...	Yellow
Remaining Colour	Red	Green	Blue	...

method, for we get the colours that we want by removing one at a time those that we do not want.

In the Sanger Shepherd method a print is made from the red record as if an ordinary lantern slide were being made, and the image produced by development is changed into a greenish blue image by toning it. Prints from the green and blue records are made in gelatine sensitised with potassium bichromate and supported on a thin celluloid film. These are dyed the proper colours and cemented on to the first with Canada balsam. The three films may be put together tentatively, and if either colour predominates or is deficient, the faulty film may be dyed more deeply, or some of the dye may be washed out, before the final cementing and binding together of the complete picture. Colour transparencies made in this way are more brilliant than is possible by any single plate (or screen plate) process because the whole surface of the picture is available for each colour.

The "pinatype" process was introduced in 1895 by Messrs. Meister, Lucius, and Brüning. In this process transparencies are made from the ordinary three negatives, and plates coated with bichromated gelatine are exposed under these, washed, and put into the appropriate dye

solution. Where the light has acted on the gelatine, it has been rendered less able to absorb water, so that the dye is absorbed to the greatest extent where the light has had the least action. Each of these dyed plates is then brought in turn into close contact with a sheet of glass or paper that has been coated with gelatine, and the dye passes partly into this gelatine film to form the picture. The final result therefore consists of only one film of gelatine into which the three dyes have been absorbed, and differs from the results produced by the Sanger Shepherd method, in which the films are separately dyed and then cemented together. Another method consists in the preparation of three carbon prints of the necessary colours and transferring these, one over the other, on to the same support.

But the possibilities of this method of colour photography are not exhausted by these more purely photographic methods. Any photomechanical method is available if three suitably coloured inks are to be had, two at least of which must be transparent to allow the other colours to show through them. Excellent work is done by collotype, photolithography, photogravure, and typographic blocks, three plates or blocks being prepared in each case, and superposed impressions taken from them in the three necessary colours. The old method of chromolithography, in which the colours were chosen empirically and the number of impressions necessary for each print might amount to a dozen or more, is now practically superseded by the three-colour process. The quality of three-colour prints varies enormously according to the skill exercised in their production. Pictures may be copied so perfectly that at a distance of a yard or so the original and the copy cannot be distinguished, or hideous things may be produced in which trees are pink and grass is yellow.

There is another section of three-colour methods, in which the colours are not of a pigmentary or dye-like

character, but are produced by optical means, interference, or dispersion, but this we refer to only to show the universality of the application of the three-colour principle, for pictures so produced are little more than scientific curiosities. We may perhaps qualify this statement with regard to a method, different from any previously described, which serves for copying coloured transparencies, but is far too slow for general work with a camera. The prepared paper is coated with a film in which are three suitable colours, so that the coating is black. The dyes chosen are such that are bleached by exposure to light, and their instability is enhanced by incorporating a sensitiser with the film. When such a prepared sheet is exposed to light under a coloured transparency, the colours of the transparency are reproduced more or less on the print because the light bleaches the colours that are not wanted. The method depends upon the fact that light can affect a substance only when it is absorbed, and therefore when a mixture of unstable coloured substances is exposed to a coloured light, there is always a tendency for those substances that are of the same colour as the light to survive the longest, because they reflect more of that light than of the others. Whatever one may think as to the possibility of a process of this kind becoming of general applicability, it must be admitted that the "Uto" paper put upon the market a few years ago by Dr. J. H. Smith was surprisingly successful, and since then Dr. Smith has made further improvements in the paper that he has recently introduced.

Thus we see from this rapid review of the methods of colour photography, that in the processes that are commercially available, the aim is not to reproduce colour but to imitate it. The perfection of the imitation depends not only upon the characteristics of the method but upon the skill of the worker, and the colour shown in the result is not impersonal evidence of the colour of the

original. But with due care, there is less liability to variation than if the whole of the colouring were done by hand, and the variation in any given series of prints is more likely to be uniform, and in any one example should be uniform over the whole of it.

CHAPTER XVI

TRUTH AND ERROR IN PHOTOGRAPHY

In the preceding chapters we have considered the nature of light and how it is controlled for photographic purposes. We have seen something of the development of photography and of its possibilities. It will perhaps be of advantage to pause before considering some of its special applications to look at photography from a more general point of view. Essayists have sometimes set themselves to catalogue the uses of photography. That may have been worth doing a generation ago, but to-day one might as well attempt to set down all the purposes that can be served by writing or printing. We can photograph everything that we can see, and many things that we cannot see or ever hope to see. As a method of recording, therefore, photography surpasses the observing power of human vision in the universality of its applicability, and it surpasses it also in its truthfulness, because it is free from personality or bias.

Sometimes we are met with the question : Can photography lie ? And we hear at different times an emphatic yes, and an equally emphatic no, given in reply. Of course photography cannot lie, because all photographic results are due to the effects of the unchanging laws of nature. But a person may be misled by a photograph, just as he may be misled by a document, by reason of his own inability to understand it. And a photographer may set himself to produce a deceptive photograph, seeking to gain a dishonest advantage for himself or his customer.

But a photograph, so long as it is a photograph and is not sophisticated by hand-painting or other such processes, must always have a definite relationship to the thing photographed, according to the conditions under which the photograph was produced. In critical cases it is no more than fair that photographs should be interpreted, when disputes or doubts arise, by those who have studied the subject, just as a legal document is taken to a court of justice when a final opinion is required as to its meaning.

The honest photographer, so far as he is really honest, endeavours to be transparently honest, and to produce work that not only *is* right, but that *appears* to be right. This is the aim of all honest persons who have to record facts. But it is astonishing how liable a man who has the very best intentions is to deceive through want of care. And on the other hand, many persons would be surprised if they knew how easily they can be deceived. These are commonplace facts that concern every phase and detail of life, including photography. If the casual observer looks at the illustrations facing page 256, it will seem to him absurd to suggest that the letters L I F E are upright and that there are concentric circles in the other figure, because the letters appear to be inclined to each other, and the circles appear as if they formed a spiral. But as the letters and the circles are as stated, the real fault is in the observer, who does not see the facts as they are. Nevertheless, a photographer who produced a picture that was strictly correct, if it produced a false impression in the minds of a large proportion of those who saw it, would merit blame, because it is the duty of one who records facts to do his best to demonstrate them also. Indeed, in some matters one might be inclined to allow a little license in fact, if the impression produced is correct, but in photography this is not permissible. The facts should be correctly re-

corded, fundamentally and absolutely, and a skilful and honest photographer will see that his record is not likely to produce any false idea.

A photograph always records a fact. A thought or an idea may be expressed in various ways, but never by photography. We cannot photograph unless there is a thing to be photographed, and all that a photograph can do is to represent that thing. A person may be dressed up to represent Hamlet, and he may be photographed. The photograph is not of Hamlet, but only of the person dressed to represent him, and whatever merit there may be in the picture as reminding one of Hamlet, has to do with the person and the dressing, and not the photography.

That a photograph always represents facts and nothing else but facts, is its chief characteristic. An artist can paint a picture of a milkman filling up his cans at the pump, and his picture may be a pure fancy, it cannot be direct evidence that any milkman ever did such a thing. But if we have a photograph of a milkman at the pump, there must have been a pump or an imitation of one, and there must have been a person dressed as a milkman, and whatever he is shown by the photograph to be doing, he must have been doing when the photograph was taken. In this sense photography cannot lie. But there might be an inclination on the part of some to consider that the photograph was evidence of facts which it has not recorded, as it is often difficult for an expert and trained person to distinguish between observation and inference, and those who have never troubled themselves about this matter generally mix their observations and inferences in hopeless confusion. In this particular example the connection of milk with the episode in any way is a matter of inference, the photograph cannot show it, and if the contents of the vessels were shown in the picture there could hardly be evidence that it was milk and not

whitewash. That the man is a milkman is simply a matter of inference from his appearance and his surroundings. If a plasterer were using a can similar in shape to a milk can, and was getting water for the purposes of his trade, the photograph would be much the same as if a milkman were fraudulently increasing the bulk of his milk. And obviously this matter might be pursued further. The photograph is right enough, the difficulty lies in the interpretation of it.

It is possible by photography to misrepresent things, and we will take a few very common examples in order to get an idea of the general character of such misrepresentations. But it must be borne in mind that every photograph, whoever takes it and whether by means of a five-shilling or a fifty-guinea apparatus, is the necessary result of the procedure, and in this sense is a mechanical production. Its errors, if any, will not be random errors such as a drawing done by hand is liable to, but they will be regular and strictly definable, if the conditions are known under which the photograph was made.

It is a rule in plane perspective that vertical lines in the object shall be shown as parallel in the picture, and this is secured by having the plate vertical during its exposure in the camera. But if the plate is not vertical —if, for example, the photographer finds that the building is too lofty to get its image on the plate as it is, and he tips up the camera, with the result that the plate leans backwards, then the scale of the image, as compared with the object, will decrease regularly from the upper to the lower part of the plate. The image of the upper part of the building falls on the lower part of the plate, so that the result in the final photograph will be that the top of the building will be represented on a smaller scale than the lower part, and so the vertical lines will be represented as converging upwards. This gradation of scale and the consequent convergence is unconventional

and liable to deceive, and therefore wrong, although it is the only result possible under the given conditions.

In the case just considered it is possible to state absolutely that the vertical lines in the object should be parallel in the picture and that any departure from parallelism is an error. We may compare this to stealing, because of it we may also say absolutely that it is wrong to take what belongs to another. But there are matters in which the error lies only in exaggeration. Total abstinence from food and gluttony are both wrong: virtue here lies in the intermediate course, which cannot be absolutely defined. No one can say after his meal that half an ounce more would be half an ounce too much, or that to have eaten half an ounce less than he has eaten would have been detrimental to him. There is a wide scope for discretion; but we are all agreed that to injure one's constitution by either abstinence or excess is sinful and may be criminal. In pictorial representation a distant object is shown on a smaller scale than a nearer object, and it must be so, because as any object approaches the eye it hides an increasing extent of the view beyond it. The gradation of scale according to the distance of the object is natural and desirable, but it may be carried to excess until it becomes a fault. It is always well to avoid having too near a foreground when the distance is included in the picture, because when the difference of scale is too great a pebble in the foreground may be made to appear like a rock, and a tree just above it in the distance may be dwarfed to a bush. It may be suggested that a pebble remains a pebble and does not seem to grow any larger when picked up and examined more closely, and that is quite true. If you will hold up one hand at about ten inches from your eye and the other at twice the distance, you will not notice any difference in their apparent sizes; but now shut one eye and while keeping both hands at the distances named bring them

into line, and you will find the nearer hand is large enough to cover four hands at the greater distance—that is, the nearer hand appears to be twice as long and twice as broad as the more distant. It is because we *know* that our hands are about the same size that they appear to be so, irrespective of varying distance, unless they are compared by bringing them into the same line. That this is a matter of experience, and not a matter of estimating size, can be shown by attempting to compare objects of which you have no experience. What round thing will be sufficiently large when held at arm's length to cover the disc of the sun or the moon? Those who have not tried the experiment will make all sorts of answers to this question, starting with a dinner-plate perhaps, while others may suggest a half-crown. As a matter of fact, a threepenny-piece is far larger than necessary. Or select a word in a printed page, and guess what coin will just cover it. Such exercises as these will show that our ideas of size fail us when we compare things that we have not been in the habit of associating together.

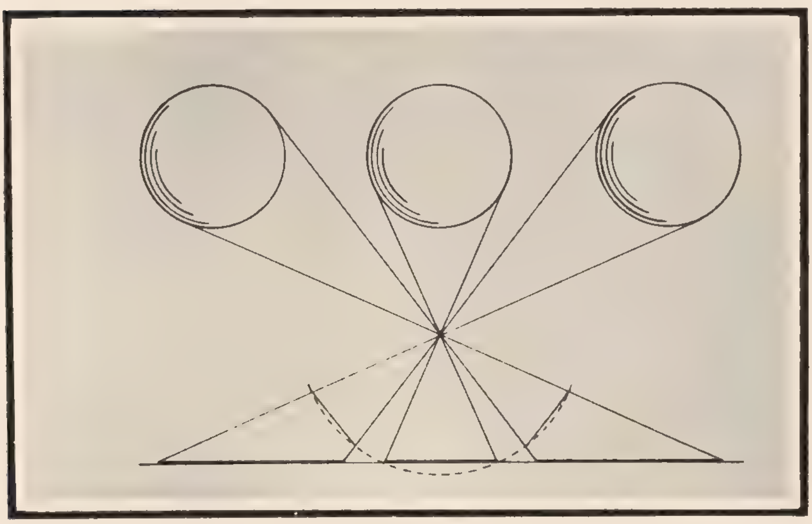
Thus we have no guide to the difference in scale permissible in the same picture, except the appearance of the picture as a whole. If any part of the object photographed is unduly near the camera, it may give so large an image compared with the other and more distant parts of the object, that the result appears grotesque if we know the thing that is represented. If we do not know the object itself, we shall probably be deceived, and it is possible for a photographer to fraudulently deceive in this way. By getting close to a small garden, he may make it appear to be almost a park, and a pond may be represented as a lake, and any one who has only the photograph to guide him, may be deceived. In this sense photography *can* lie. In all such cases the perspective will be correct if proper care is taken, though it is what is called "violent"; and if the picture is put

in an apparatus that obliges one to look at it with one eye from a certain correct position, the suggestion of exaggeration will disappear, and the representation of the object will be true to it. But without this limitation in the manner of viewing it, such a photograph must be condemned.

There is another peculiarity in plane perspective, or the picture as given by a lens on a vertical plate, due to the flatness of the plate. Suppose that a row of round or similarly shaped objects, such as a row of pillars, persons, statues, or balls, is photographed, and suppose that all the pillars, persons, statues, or balls are of the same diameter, they will not be represented as of the same diameter in the photograph. This is a simple result of the conditions, and to a certain extent is necessary for the correct representation of the things, and, as in the previous case, the fault lies in the exaggeration. It is quite easy to understand the reason for this difference by an examination of the lower figure facing this page. The round objects are shaded, and the marginal rays from each are represented by lines which indicate the extent on the plate of the image of each object. The increased size of the marginal images is due to the obliquity of the light rays that fall upon the plate, and means therefore a radial extension of the image in every direction from the plate centre. In photographs of public functions that take place in rooms, the restrictions as to space often oblige the photographer to have some of the people quite near to the camera and to include a wide angle of view. Those persons that are represented near the margin of the plate will appear perceptibly stouter than they really are, or if they are sitting down, their heads may be seen drawn out into quite an unnatural shape. The author has such a print in which one gentleman's head, the nearest to the camera and therefore the largest in the picture, comes unfor-

RETICULATION

Example of the reticulation of a gelatine film. This was obtained accidentally, and is very coarse. It shows clearly the general character of this phenomenon.



DISTORTION AT THE EDGES OF THE PLATE DUE TO ITS FLATNESS

As the rays that form the image fall obliquely on the plate towards its edges, the image is spread out in a radial direction. If the plate were curved, as shown by the dotted line, the image of the more distant object would be narrower than that of the nearer object.

tunately near to the corner of the plate, and his head is extended to such a great degree and askew that one dare not reproduce it. But the two illustrations that face page 206 show the effect on inanimate objects that cannot object to their misrepresentation. The one is a terrestrial globe, and this fact may be accepted as sufficient evidence that it is for practical purposes a sphere, but by photographing it so that its image falls near the edge of the plate, its image is drawn out into an egg-shaped figure, and the other is a cylinder that is higher than wide, but in the photograph the width is represented as greater than the height. These two examples are not at all such extreme cases as might have been selected, but they serve to show how careful a photographer should be not to include too great an angle of view. This kind of distortion, as in the previous case, disappears entirely if the photograph is looked at with one eye from the correct view point, and indeed is then necessary in order to properly represent the objects. But as photographs are not generally examined under such restrictions, it is an error to produce pictures that need them in order to appear correct.

The above errors relate to "drawing" or shape. In the previous chapter we have referred to the effects of colour and its reproduction, and the only remaining item in photography is the gradation, or the reproduction of light and shade. Here also error is possible, and the statement that was made some time ago by a misled enthusiast, that the character of a photograph is settled as soon as the cap is put on the lens (that is, at the conclusion of the exposure), is not correct, although it has often been quoted as authoritative. The exposure has something but not everything to do with this matter, it is affected by other circumstances too. The author has had to do with a case in which the vital question was as to the visibility of things through

a certain mist or smoke and whether this was truly or deceptively represented in certain photographs. In such a case the photograph may be true or false. The mist itself is represented in the print by a patch of blankness, or very nearly that, and whatever is seen through it is seen feeble and white in proportion to the opacity of the mist. If the negative is under-exposed or made with too much contrast, or if the print is under-exposed, then the objects visible through the mist or smoke will not show as clearly as they should, or they may not show at all, and thus the opacity or bulk of the mist will appear in the print to be greater than it really is. The test in this case also is to compare the photograph with the thing that it represents, and to see that it is of such a nature that one who has not seen the object itself would be able from the photograph to imagine it correctly.

It should be noticed that what we have called errors are nothing more than the natural results of the procedure that leads to them, that they are generally caused by a want of judgment on the part of the photographer, and that it is easy to know in what direction such errors are possible or likely. There are other errors possible, due to imperfections in the materials used. A bubble in the emulsion coating on the plate causes a deficiency of emulsion at that point, and therefore a thin place and a dark spot on the print. Opaque specks of dust on the plate will give white spots on the print. These may seem trivial faults and in ordinary cases are readily removed by a little Indian ink or water-colour, "spotting" as it is called; but if the subject itself consists of spots, such as a photograph of the stars, a fault of this kind may lead to uncertainty. There can be no certainty that such faults are ever eliminated, for the air is full of particles; if therefore the presence or absence of a small spot is a vital matter in a photograph, two or perhaps three negatives must be taken. A spot that is due to

the object photographed will appear on all the plates, but the probability that an accidental spot of the same character should happen to come in exactly the same place on two or three different plates is extremely remote. Other errors are possible due to irregularities in the emulsion or the coating, such as a difference between the edges of the plate and the middle, and while these are not frequent and rarely obtrusive in ordinary work, for more exact purposes the possibility of them has to be borne in mind.

We have already remarked that no lens can be perfect. We want all the light that falls upon a lens to pass through it and so to form as bright an image as possible, but when light falls upon a glass surface some of it is always reflected, and if the reflected light simply passed away and was lost there would be but little trouble, as it would mean at most a little longer exposure to make up for the lost light. But lens surfaces are curved and the reflected light is sent from one to another, and the curved surfaces act as mirrors and form other images than the main one. By holding a lens at a little distance from the eye and looking through it at a candle or gas flame, a number of these images produced by reflection will be seen, six if the lens is of the "rapid rectilinear" type, and fifteen in the common type of portrait lens: more in the latter case, because there are six lens surfaces instead of four as in the rapid rectilinear. This reflection cannot be got rid of, so the optician aims at getting the images formed by it far from the plate that they may be as much out of focus as possible, and the light spread as far as possible over the whole plate. Success in this attempt varies, and in the use of lenses for critical or scientific work this interfering circumstance must not be lost sight of. The amount of light reflected is only a small proportion of the whole; these false or ghost images are therefore comparatively feeble, but if any part of the

chief image is very bright, they may be obtrusive even to the casual observer. The author has a photograph of a gentleman in evening dress in front of a grey background, taken by a professional photographer in the ordinary way of business, and above his head there is a triangular patch of light which was a source of annoyance and mystification to several photographers. This patch is nothing else than a ghost image, produced by reflection from the lens surfaces, of the man's shirt front. This explanation of the patch of light was not readily accepted at the time, but investigation proved that it was correct.

This reflection, instead of giving a subsidiary or ghost image of a bright portion of the object (of course an image of the whole object is formed, but the image of the less bright parts is generally too feeble to produce any noticeable effect), may give an image of the diaphragm of the lens, if one of its reflected images is approximately in focus on the plate. This image will be always in the middle of the plate, that is opposite to the lens, because the diaphragm is central to the lens. It will probably be more obtrusive when the diaphragm has a small aperture than when it is opened out to a larger, indeed in the latter case it may be so diffused as to disappear. These central spots are called "flare spots."

We have not described all the unwelcome and interfering effects that photography is liable to, but we have said enough to show that the photography of even common objects is not the simple matter that so many imagine it to be. And when we come to critical or scientific work, it is easy to see that the most careful work by one who has not seriously studied the subject may be not only insufficient but actually false and misleading. This fact is rarely appreciated by those to whom the public looks for guidance in educational matters, and even those whose work depends upon photography generally neglect it whether

they are cognisant of it or not. Indeed we may go further and say that those whose livelihood depends upon photography often do not appreciate it, except to a certain extent now and then, when they suffer inconvenience and it may be much pecuniary loss that might have been avoided if they had taken the trouble to see that their procedure was founded on true principles.

CHAPTER XVII

INSTANTANEOUS PHOTOGRAPHY AND THE PHOTOGRAPHY OF MOTION

THE words instant and moment are very useful though very indefinite. We have been told that there is no such thing as an instantaneous exposure in photography because every exposure is of a measurable duration, but it is not usual to restrict the word instantaneous to the meaning of a geometric point of time, and indeed if the word were so restricted we should have no practical use for it. We generally regard about the tenth of a second as the longest exposure that we should call instantaneous, and there is a good reason for this, because it is about the shortest period for which it is possible for us to see anything. When we shut our eyes we do not immediately cease to see what we were looking at, and if we shut and open our eyes as quickly as we can, vision remains continuous although the light was stopped for a moment from entering our eyes. The effect on the eye, or we may say the picture produced on the retina, lasts for about the tenth of a second, so that if we look at an object that is illuminated by an electric spark that lasts for only the millionth part of a second, although the actual image of the object was on the retina for only this minute period, we see the object for about the tenth of a second because the effect on the retina persists for so long. And if the illumination lasted for a thousand millionths of a second, we should still see it for about the same time—we continue to see it after it has ceased to be visible until the effect it has pro-

duced has died away. It may be thought impossible to see a thing after it has ceased to be visible, or ceased to exist (as in the case of the spark itself), but it was pointed out in an early chapter that some of the stars that we see may, so far as we can tell, have ceased to shine thousands of years ago, for we are so much behindhand in our observations because of the time that it takes light to travel over so great a distance as that which separates us from them. That we really see things after they have passed away is commonly illustrated by swinging a lighted taper or anything of the sort, when the light becomes a streak that is longer the more quickly the taper is moved, because we not only see the flame where it is, but also where it was about the tenth of a second before, and in all the intermediate positions. We shall see the importance of this "persistence of vision" in the later part of this chapter, meanwhile it gives us a key to the meaning of the word instantaneous. There is another reason why photographers generally adopt such a meaning, and that is that the tenth of a second is, in shortening the exposure, the first exposure that requires a contrivance to give it. By removing and replacing the lens cap as quickly as possible by hand, the exposure given is equal to about the quarter or fifth of a second, and for anything shorter than this we must have a "shutter," or some equivalent device.

From the earliest times of the Daguerreotype, when persons would sometimes have their faces whitewashed in order to shorten the tedious exposure by a few minutes, the aim has been to reduce the period of the exposure necessary. With ordinary lenses portraits now need exposures of only a second or two indoors and a mere fraction of a second out-of-doors. We may roughly say that the most rapid exposure that will serve, as of performing athletes, out-of-doors with the best summer light and other advantageous circumstances, is about the one five-hundredth part of a second. Such an exposure is rarely

given, even by those who have apparatus marked to give it, but we may consider it as the practical limit. If we dispense with the camera and get a powerful electric spark to shine directly upon the plate, the object to be "photographed" coming between the plate and the light so that it casts a shadow on the plate, the limit at present is approximately the one-millionth part of a second.

The exposures just mentioned may be regarded as the very shortest; the great majority of instantaneous exposures come between the tenth or fifteenth of a second and the fiftieth of a second, for although many shutters are marked to give the one-hundredth part of a second, a very great number of them when set to this figure do not give a shorter exposure than the thirtieth or fortieth of a second. The exposure necessary to produce a proper effect upon the plate is calculated in exactly the same way as when longer exposures are given, and it can be shortened, while remaining effective, only by increasing the aperture of the lens or getting a more sensitive plate. By choosing a brighter day, and if one is photographing an athlete, having him dressed in white rather than black or red, and getting on the brighter side of him if the sun shines, will help to get a sufficient exposure effect in a shorter time. If because of the rapid movement of the object the exposure has to be shorter than will give a "properly exposed" plate, then the under-exposure must be accepted and made the best of. Here there is room for special skill and experience.

Photographers talk glibly about short periods of time, such as the one-hundredth of a second, and while this is a perfectly definite period, when applied to a photographic exposure it may mean three different things, because there is no shutter or other mechanism that will open in no time, remain open for the period required and close in no time. Some of the total time is taken up in the opening and closing, and at these times the lens is not fully open.

If the shutter is arranged as a blind with an opening that is drawn across the front of the plate, "focal plane shutters" they are called, the same considerations apply. The opening begins at zero and gradually increases to the full, then gradually decreases until it is closed. The proportion between the total time occupied and the time that would be necessary to produce the same effect on the plate if no time were occupied in the opening and closing, is called the "efficiency" of the shutter. When a short time, such as the hundredth of a second, is stated in this connection, it may refer to any period between the total duration of the exposure, and the shorter time that would produce the same effect if the lens were fully open all the while. The proportion between these two varies very much according to the instruments themselves and also according to the conditions under which they are used.

The advantage of being able to secure a photograph in such short periods as those we have been discussing, is that moving objects may be photographed while they have time to move to so small an extent that the photograph is not blurred beyond a negligible amount. The faster an object is moving the shorter must be the exposure, but the mistake is often made of considering only the rate of progression of the object. A man may be walking at four miles an hour, but each foot will move at considerably more than eight miles an hour when it is at the middle of its swing. If the photographer is skilful enough to expose at the moment when both the man's feet are on the ground, then the more rapid movement may be ignored. In many other cases there are advantageous moments of this kind that will permit of a longer exposure being given than if the most rapid movement of the subject were allowed for.

Instantaneous exposures may be given with any kind of camera, and it is often of great advantage to have the

camera firmly supported on a stand. But one reason for desiring short exposures is that the stand may be dispensed with and the camera merely held in the hand while the exposure is given, the movement of the person holding it becoming negligible by reason of the shortness of the exposure. Most persons will not move a camera far enough to affect the result in the twentieth of a second if they try to hold it still; with practice this may be extended to the tenth of a second, and with a few persons to the fifth. Cameras made for use in this way are generally called "hand cameras," but of course if there is a convenient post, tree, window ledge, wall or other suitable object upon which the camera may be rested, the wise photographer will avail himself of such support.

The great convenience of having a camera in the hand, ready at a moment's notice, as compared with a camera that has to be got ready, set up and mounted on a stand, must have been obvious from the first, but until gelatine dry plates were commercially produced such an apparatus was not worth troubling about, because the plates available were not sufficiently sensitive to make them effective. In 1881, Mr. Thomas Bolas devised several "detective" cameras, as they were called, presumably because of their possible use to detectives in getting photographic evidence that might be useful to them when the cases they were investigating came into court. For some years this name remained in use, and the idea was to have a camera that could not be recognised as such, so that photographs might be taken in the street or in other public places without the knowledge of the passers-by or the persons being photographed. A common arrangement was to have the camera outwardly resembling a brown paper parcel, and later on it was concealed under the waistcoat, the lens taking the place of one of the buttons, or under the tie with the hope that the lens might be mistaken for the head of the tie-pin. But as the number of such secret

cameras increased the more rapidly were they recognised, and adding to this fact the necessary attention of the photographer to his apparatus and the special movements necessary to make an exposure, there is good reason to doubt whether "detective" cameras ever really served their purpose in secret.

In giving up the notion of secrecy, the way was opened to consider convenience only, and this has led to the introduction of innumerable patterns of hand cameras. Some of them fold up and are therefore more convenient for carrying, but need more preparation before they are ready for an exposure than the box form in which the lens and plate are always in position ready for use. Of course a camera intended for use on a stand, an ordinary "field" camera, if it has a shutter on the lens, can be used as a hand camera, and some excellent large photographs of yachts have been taken in this way, but such cameras are often inconvenient to hold, and if pressed against the body to keep them steady, the focussing adjustment is liable to be interfered with. And almost all hand cameras may be fixed upon stands, so that there is no radical difference between the two types.

In the use of a hand camera, it is desirable if not always necessary to have a special means of knowing when the image of the object to be photographed is properly in position, so that it will fall upon the plate as desired when the shutter is opened. If the object is moving it may be necessary to follow it so that the shutter may be released at exactly the time when it has arrived at the position desired. A great deal of ingenuity has been expended on the construction of "finders." One of the commonest is merely a small camera which is fixed to the main camera and gives a picture about the size of a postage stamp, the same that will, on a larger scale, fall upon the plate. The small picture can be watched all the time. The "reflex" form of camera is a favourite with

many in spite of its bulkiness, because this gives a full size picture of the object that can be watched up to the moment of exposure. Only one lens is used, and a mirror behind it reflects the image up to the ground glass at the top of the camera until the shutter release is touched, then the mirror moves out of the way immediately before the shutter gives the exposure.

What is the particular use of a hand camera? Probably the greater number are only toys in the hands of their owners, and used for making snapshots of anything that happens to strike their fancy. It may seem surprising at first that so great a number of the photographs taken in such a haphazard way are successful, and it is sometimes argued from this, by those who know nothing or little about the matter, that photography as an art does not need serious study. The measure of success in this direction, whatever it may be, is due largely to the fact that those who merely "press the button" generally use their cameras in fine weather and on subjects that require very similar exposures. It is also due largely to the fact that those who supply them with cameras, plates, films, and printing papers, know their habits and provide them with materials that will best suit the treatment that they know they are likely to receive. In short, we may say that all the photography is done for them, and they only follow a few simple instructions. This snap-shotting is a form of amusement that deserves commendation, because it is generally interesting and harmless, it does a little towards training the powers of observation of those who practise it, and it may lead them to engage in more useful work.

But hand cameras are also largely used for the getting of photographic records under conditions that would render it very inconvenient if not impossible to fix up a stand. The photographs of current events that we have become accustomed to expect in daily papers, the photo-

graphs of living things of all kinds, animals, birds, insects, reptiles, and fishes, that are rapidly rendering obsolete the pictorial representations of them that we were accustomed to a generation ago, and innumerable other subjects both indoors and out-of-doors, are often more conveniently photographed with a hand camera, either because of its portability, the rapidity with which it can be got ready for use, or its special adaptations, for their use is not confined to subjects that need very short exposures.

The photographic shutter acts by admitting the light to the lens and so to the plate for the necessary period, but if the light itself exists for only the desired period there is no need for the shutter. The lens may be uncovered shortly before the light comes and closed after the exposure. This is the method of photographing lightning, but as one cannot tell when the flash will come, the lens must be opened and pointed towards that part of the sky where it is most likely to come. The duration of the light determines the duration of the exposure. The same condition may hold with artificial lights, in the use of which it is often more convenient to regulate the exposure by the light rather than by the shutter. By blowing finely powdered magnesium (or aluminium) through the flame of a spirit-lamp a bright flash is obtained, and the brilliancy of the light may be roughly regulated by the quantity of powdered metal used. This is a common method of illumination when photographing guests at dinners or other functions, and by india-rubber tubing several flash lamps, each containing its dose of magnesium, may be actuated simultaneously and a large hall may be sufficiently illuminated. A flash of this kind will probably range from about a quarter of a second up to a second or so according to the quantity of the metal and the suddenness of the puff that blows the metal into the flame.

A much more rapid and also brighter flash may be

obtained by mixing the powdered magnesium with some substance that contains the oxygen necessary for its combustion instead of simply allowing it to burn in the air. Such a mixture is analogous to gunpowder and should never be prepared or used by anyone who does not know how to handle explosives. Of these mixtures some are more dangerous than gunpowder, and others that are less risky have sometimes been the cause of deplorable accidents. If carefully prepared, a few grains of one of these mixtures will give a flash that lasts only about the twenty-fifth of a second. But by a suitable arrangement a bright electric spark may be obtained that lasts for only about the millionth part of a second, a duration that it is impossible to conceive. In the millionth of a second, a bullet from a rifle has scarcely time to move a perceptible amount, and by arranging for a bright spark that the bullet itself will cause to pass by completing the contact of the electric wires, and fixing the apparatus so that the bullet as it flies passes between the spark and the plate, the plate will be made developable except where the shadow of the bullet falls upon it. This is the way that allows one to photograph a bullet travelling at full speed. Drops of water as they fall, soap bubbles as they burst, and other rapidly moving objects, have had the nature of their movements ascertained by similar means.

Closely connected with the photography of moving bodies is the photography of motion, by which we mean the photography of a moving body at various regular periods of its movement. Having such a series of photographs arranged in order, by running the eye along them we see the various stages of the movement, and by letting our imagination fill in the gaps, we get a very good idea of its character. It is better still if such a series can be put in an apparatus, which as a toy used to be called a "zoetrope" or "wheel of life," because when it is rotated the succeeding pictures rapidly take the place of each

Edgar Scamell

THE LIFE HISTORY OF A NASTURTIUM

30th May	6th June
16th June	6th July

These and those on the succeeding plate are selected from a series of nearly a hundred photographs, taken one every day during the life of the plant. Such a series arranged in a

(*See page opposite.*)

Edgar Scamell

THE LIFE HISTORY OF A NASTURTIUM

16th July — 23rd July
2nd August — 22nd August

suitable cinematograph apparatus will show in a few seconds the movements of the plant during its development that in fact were spread over a period of about three months.

(*See page opposite.*)

other, with a little interval between which is too short for the eye to recognise. The illusion of movement is then complete. The subjects shown in such apparatus are generally in rapid motion, such as running horses and jumping men, but the instrument is available for the investigation of movement of any sort, and if the photographs can be secured, a very rapid movement may be slowly reproduced and its details clearly seen, or a very slow movement may be shown more quickly that its character may be more easily appreciated. As an illustration of the latter, Mr. Edgar Scamell a few years ago photographed a nasturtium plant every day for eighty days, beginning when the plant first appeared above the ground and continuing until it was fully grown, and the seeds ripe and falling from their vessels. The growth of a plant is so slow that it is impossible by the unaided eye to trace it, but by showing such a series of photographs in the way described, the whole process may be seen as if it occupied only a few seconds instead of eighty days. The following are the chief dates of the progress: 2nd May, seed planted; 21st May, first appearance above the soil; 16th July, buds formed; 23rd July, flowers opening; 2nd August, seed formed; 22nd August, seed fully grown and fell. By the kindness of Mr. Scamell eight of this series are reproduced, and they will serve to show the general nature of the whole.

But it is chiefly with regard to rapidly moving objects that the photography of motion is associated, for here the eye cannot see the various positions of the moving object, and, judging only from the general effect of the movement, the spectator is often very much deceived as to its details. If not the very first work, the first successful work in this direction appears to have been due to Mr. Muybridge of California, and was undertaken by him in 1878 or 1879 in order to decide a wager. The point in dispute was as to whether a trotting horse at any stage of his movement

had all four feet off the ground at the same time. Mr. Muybridge arranged a platform along which the horses were to trot, with a series of cameras fitted with rapid lenses and quick shutters, and arrangements by which the horse automatically released the shutter as he passed in front of each camera. This apparatus was subsequently improved, and Mr. Muybridge devoted himself for many years to an analysis of the method of progression of various animals, including human beings. Similar investigations were carried out by M. Marey of Paris, but with a simpler apparatus and one that would permit of dealing with movements, such as jumping, that do not include a sufficient change of position to conveniently bring the subject in front of another camera. He started work in 1882 and used a single camera, and by a rotating shutter that rapidly opened and closed the lens alternately, he obtained a large number of photographs of the subject on the same plate. These photographs would overlap, but that was no drawback, indeed sometimes it was an advantage in tracing the rate and character of the movement so long as the outline or any conspicuous part was visible to represent the desired part. The movement of the foot of a jumping man, for example, could easily be traced if only the outline of the heel was shown in the photograph. In the following year M. Marey constructed a photo-physiological studio, with chronographs, scales, and other conveniences for exactly registering the times and distances concerned. In order to get more precise details, he sometimes dressed his subject in black so that he did not show against the black background, and put a bright narrow stripe to indicate, for example, the leg and foot. Thus the part desired was represented in the photograph by a mere line, and this enabled one hundred instead of only ten exposures per second to be made without confusion.

Later on M. Marey photographed the movements of fishes swimming in a tank and birds flying in the air, as well as of men and animals, with remarkable success.

A simple method like that just described is still probably the best for the analysis of the movements of living creatures, but obviously its applications are purely scientific, for the movement cannot be reproduced upon the screen or in a "wheel of life," because the separate photographs overlap. And there was always a popular side to this kind of work, for it was realised that if a series of photographs could be taken with sufficient rapidity and shown upon the screen like lantern slides, also with sufficient rapidity, that instead of the picture-like stillness of the figures on the screen as shown by an ordinary slide, the figures would appear to move as in reality, and we should have "animated photographs." It was possible to make films or plates sensitive enough for the purpose when used in conjunction with specially rapid lenses, so that the actual difficulty was a mechanical one. It is necessary for this purpose to make a continuous series of photographs, about sixteen every second, and to go on at this uniform rate until the movement is completed or a sufficient record is obtained. It is easy to open and close the lens at this rate by the use of a disc that rotates in front of it and has openings or gaps in it. But the movement of the strip of film is not so simple. It is not enough to simply draw this along continuously, for in that case every picture would be taken on a moving film and be blurred in consequence. The film must move while the lens is covered, remain stationary for the fraction of a second that it is uncovered, then move on again, so that it must be as it were jerked on exactly the correct distance about sixteen times a second, and always remain perfectly still while the lens is open. And these movements must be

so smooth that the apparatus itself remains perfectly steady. If it were to vibrate, as many motor vehicles do when standing with the engine running, the pictures would be blurred and useless. Every one knows that these difficulties have been overcome, for "living pictures" can be seen in every large town.

This strip of photographs, which may measure anything up to about five hundred feet, is a negative. A print, that is another strip of equal size, is made from it by exposure and development, and this strip is passed through the projecting lantern under the same conditions as the negative was taken in the camera. Those who have seen cinematograph displays know to what degree of perfection the apparatus has been brought.

We have described how transparencies for use as lantern slides can be made "in natural colours," but the getting of cinematograph views in natural colours is a very different matter. We might make three films, one each for the redness, greenness, and blueness of the moving subject, and we might perhaps be able to get these three films to run so exactly together as they were being exposed, that any discrepancy would not be noticeable. We could make three prints, and by the use of three lanterns or a triple lantern project the images on the screen as we have already described in connection with the photography of colour. But for this triple projection method it is necessary that the three coloured pictures shall *exactly* coincide on the screen, and the least discernible fault in this matter is fatal. It is possible to admirably succeed in this superposition when the transparencies and the whole apparatus is quite still, but to have three films jerking forward sixteen times a second so exactly together, and to have the whole apparatus so perfectly steady, that the three images shall always be exactly

superposed on the screen, needs a mechanical perfection in the apparatus that can scarcely be hoped for. The most persevering attempts made so far have signally failed. It must be borne in mind that the single cinematograph picture is only about the size of a postage stamp, and that when this is projected on the screen the amount of enlargement is very much greater than is usual with an ordinary lantern slide, and that all errors and accidental movements are proportionately magnified.

In 1902 Mr. G. Albert Smith, in conjunction with Mr. Charles Urban, set himself the task of investigating the proposed methods of cinematography in natural colours, and of further working along the most promising lines. It was about four years ago that they began their exhibitions by a method that, if it is not scientifically perfect, is satisfying to the eye, and this is really all that is sought for and all that is necessary for popular displays. A single film is used, so that the difficulty of getting two or more pictures to simultaneously coincide upon the screen is done away with altogether. The colour photographs alternate on the same strip of film. It is easy to see that if the red, green, and blue photographs follow one another instead of being projected on the screen at the same time, that they must follow each other so quickly that the three pictures are on the retina at the same time, for it is only by combining them that the desired colours are produced. To ensure this, the photographs must be taken and shown at three times the rate necessary for ordinary cinematograph pictures, and to represent the subject for the same time the film must be three times as long. To modify these exacting and costly conditions Mr. G. A. Smith endeavoured to reduce the necessary colours to two, and in this he has been practically successful. He uses an orange red and a

bluish green filter, and the limitations which this restriction imposes are found to be negligible for this purpose. The pictures are therefore taken at a double rate, about thirty-two per second, and the two colour filters arranged on a rotating disc come alternately in front of the lens. A print is made from the strip in the usual way, and this when passed through the bioscope lantern at the double rate only needs the two alternating colour filters in front of the lens in addition to the usual apparatus.

The methods of using the bioscope or cinematograph refer to standard instruments which are constructed so that they may carry any standard films, and the method of seeing the pictures is that of the ordinary optical or projection lantern. Apparatus has been devised in which the series of photographs is taken in a spiral on a glass plate. The series of prints has been arranged as leaves in a little book which, by bending it with the thumb at the edges so that the leaves are released one at a time, brings the pictures into view in due order. And there have been other modifications of apparatus and methods that need not be referred to.

Cinematography is at present in its infancy, so that there is almost as much interest in the fact that it is possible to represent motion and in the methods of doing it as in the subjects represented. As this interest appeals to the general public, many of the subjects are trivial and only aim at being amusing; many of the films are photographs of made-up scenes arranged to imitate railway accidents, military assaults, and other exciting and tragic incidents; but there is evidence that this sort of thing is having to make way for the representations of real events. The instructional value of "living pictures" far exceeds that of the ordinary lantern slide in many cases, and this fact is being growingly appreciated. The ad-

vantages of the cinematograph are being recognised also for the purposes of investigation, and there is no room for doubt that in due time the apparatus necessary for its practice will take their proper places as scientific instruments, as the "magic" lantern did about a generation ago, and the microscope rather earlier than that.

CHAPTER XVIII

ON SIZE AND SCALE

It often happens that the photographer working under ordinary conditions finds that the picture of the object that he photographs is not of the size that he wishes it to be. It may be so large that only a part of it will come upon the plate he is using, or it may be so small that the greater part of the plate is wasted. We want to be able to photograph things of all sizes, even down to the most minute, but a picture of a fly produced on the same scale as the portrait of a man would be of little service. We propose to devote this chapter to the consideration of the control of the size of the image, and we will begin with large objects, such as landscapes and buildings, and pass gradually to the most minute which are far too small for the unaided eye ever to see.

The amateur with his one lens does not set up his camera a hundred yards away from a person he wishes to photograph, because he knows that at that distance the picture of the person would be very small. He comes nearer and nearer, and if he could watch the image on the ground glass he would see the portrait growing larger at every step, very slowly at first, but more rapidly as he approached the subject. He regulates the size of the image by altering his distance from the object. But every one who knows a little about the rules of perspective, knows that the representation of an object changes as the view point changes, so that the picture of a person ten yards away will not be the same as a picture of

him at a distance of five yards, even if the smaller picture from the greater distance were enlarged to the size of the other. The picture will be different at every different distance, and being different presumably some will be more satisfactory than others. What applies to a person applies to all solid objects, so that it is not desirable to regulate the size of the image by the distance of the camera from the object; it is preferable, when the distance is within control, to find the position that will give the best picture, and to regulate the size of the image in some other way.

This other way is to adjust the distance of the plate from the lens, for the farther the plate is drawn back from the lens the larger will the image be. At twice the distance the image will be twice as long and twice as high. But this means the use of another lens that will give good definition at the required distance, because by altering the distance the image given by the first lens will be put quite out of focus. A professional view photographer who knows his business will carry a "battery" of lenses, a dozen perhaps of different focal lengths, so that after having decided on the best position, he can get the picture he wants of the size he desires.

If the image given by the object is far too small, either because the object is distant, like a mountain peak or a castle on the other side of a lake, or because it is small, like a flower, a butterfly, or a bird, we may find that a lens of three or four feet focal length or more would be necessary to get the image the size we want. Of course the camera would have to be long enough to hold the lens at one end and the plate at the other, and a camera of this length would be a very awkward instrument; it would be troublesome to manipulate and the ordinary tripod would not support it securely. It would obviously be possible to take a smaller photograph and then make an enlargement from it, but this might be more trouble-

some and would often yield a result inferior to a direct photograph. The telephotographic lens exactly meets the difficulty here represented. Its name associates it with distant or telescopic objects and so far it is unfortunate, because it is just as serviceable for near objects. It is simply a "large image" lens, as the author pointed out when it was introduced, and it gives a larger image than an ordinary lens would with the same length of camera. Using only a moderate power the length of the camera needed for the same size of image may often be reduced to the half of that necessary with an ordinary lens, and with higher powers the reduction may be very much greater.

A telephotographic lens consists of an ordinary photographic objective with a duly corrected concave lens between it and the plate. The added lens may be fixed with regard to the other, the whole forming a compound lens that is used exactly like any ordinary objective, and behaves in the same way except that the image is larger than the length of the camera would otherwise permit. But the magnifying power of the added lens depends upon its distance from the lens with which it is associated, so that it is generally most convenient, and it is usual, to have this adjustable.

Since telephotographic lenses were first put upon the market by the firm of Dallmeyer, they have become a necessary part of the equipment of photographers in general practice, but they are of especial use to those who are interested in certain kinds of work. The general appearance and outline of a mountain peak which is characteristic from a distance, will often become so altered on approaching it that it not only loses its grandeur, but it may actually become unrecognisable if not lost to view by the insignificant intervening rocks coming into undue prominence. It may be that the only position from which one can get a due sense of the proportion of the peak is

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J. H. Dallmeyer, Ltd.

THE CLOCK TOWER, WESTMINSTER

These views show the effect of a telephotographic lens. The lower photograph was taken under ordinary conditions. The upper picture was obtained without shifting the camera or even extending it, but by replacing the ordinary lens by a telephotographic lens—the "Adon." Although the enlargement is so considerable, and the light available is consequently spread over so much larger an area, the telephotographic lens gave a sufficiently brilliant image to render it possible to keep the duration of the exposure short enough to avoid any blurring of the representation of the moving traffic.

from a distance of many miles, but an ordinary photograph taken from this position would include a wide stretch of country with the only interesting feature in the picture so mixed up with other details that it would need to be marked for the purpose of identification. From the same point of view the telephotographic lens would give a picture larger to any desired extent, so that either the peak alone would be shown, or just so much of the range of mountains might be included as the photographer considered desirable. Then there would be no more need to indicate which was the peak than there is to mark what represents the man in a portrait of him.

A cathedral as a whole may be photographed either outside or inside, and many of its parts, such as doors, windows, and ceilings may be portrayed without using any other than the usual type of photographic apparatus. But if the chief interest lies in the gargoyles, or in the carvings of the capitals, it is very likely to be impossible to get sufficiently near to them to get them on a large enough scale to show their details. The telephotographic lens will give a large and well-defined image, which will have the additional advantage of representing the detail as it appears from the position that it is seen, and meant to be seen from.

Animals in their natural haunts would often be disturbed if the photographer approached them in order to photograph them as a domestic dog or cat might be photographed. The telephotographic lens enables him to keep at a much greater distance without getting a uselessly small picture. All sorts of devices have been arranged, and many apparently insurmountable difficulties have been boldly faced in order to get true pictures of birds and animals as they really are in nature. Sometimes the photographer will conceal himself in a small erection made to imitate the surrounding bushes and foliage, so that the bird's suspicions may not be aroused. He may have to

take up his position hours before it is expected to return to its nest, for fear of frightening it away. Some birds build only in high trees, others on the face of cliffs, and seeing the photographs that have been published by the brothers Kearton we cannot say that any such places are inaccessible, but it is obvious that it must be an advantage to have the restrictions as to the distance of the camera made less irksome.

It is rarely if ever that a gain can be realised without some loss that modifies the advantage. The chief difficulty with regard to the use of telephotographic lenses is the protracted exposure necessary. If the image that the lens would give without the added lens which converts it into a telephotographic lens is magnified two diameters, the light available to form the image is spread over four times the area—it is of only one-fourth the brightness; the exposure must therefore be four times as long. By the same reasoning a magnification of eight diameters requires an increase of the exposure to sixty-four times its original duration, which is practically a minute for every second. A magnification of eight diameters would increase the size of a postage stamp to about eight inches by six, rather larger than the page of this book, or a bird that was represented by an image about the size of the end of a lead pencil would at this rate be enlarged to the size of a five-shilling piece. The only way to reduce this increase of exposure is to use a lens of large diameter to begin with, and this is the reason why telephotographic lenses intended for natural history work are so large and heavy.

If the object that we have to deal with is under perfect control—suppose for example that it is a postage stamp—the camera with its lens may be brought nearer and nearer to it, and the image if sharply focussed will then become larger and larger. At a certain stage the image and the object will be of the same size, and that will be when they are equally distant from the

centre of the lens. With such a lens as is ordinarily used for plates four or five inches long, the stamp will now be about a foot in front of the lens, and the focussing screen with the sharp image on it will be about the same distance behind it. If now the lens is brought three inches nearer to the stamp, the image will be formed six inches farther away on the other side of the lens, and it will be twice as long and twice as wide as the stamp itself. Reduce the distance between the lens and the stamp by another inch and the image will be another six inches farther away on the other side, and it will show the stamp enlarged three diameters. The relative linear measurements of the object and the image will always be proportional to their distances from the lens. By this method we can control the size of the photograph of the stamp until the image is produced so far behind the lens that the full extension of the camera has been brought into use. It is exactly the same method referred to above by which the size of a portrait is regulated, but extended until the size of the image exceeds that of the object.

Clearly such a method as just described is applicable only in the case of small objects, because the size of the photograph is limited by the size of the plate. And as for general purposes of illustration it is never desirable to have the picture larger than the object, this method finds its chief application in scientific work. The structure of flowers, insects, minerals, and similar things is often rendered more clear by a little magnification, and just as those interested in these matters generally carry a pocket lens to assist their eyes, so the photographer finds advantage in having his picture somewhat larger than the original. But this method of increasing the size of the image soon reaches its limits because of the restricted length of ordinary cameras. To give an increased range cameras are made with an extra long

extension, giving up portability for the sake of a greater range. But here too the practical limit is soon reached, for a camera five feet long will give a magnification of only nine diameters when using a lens of six inches focal length. By substituting a lens of three inches focal length the magnification would be doubled, and a one-inch lens would give rather more than six times as much, practically a magnification of sixty diameters. But we have now passed to optical conditions which are different from those that the maker of ordinary photographic lenses seeks to satisfy and entered upon microscopical work. Here we must endeavour to be able to push our magnifications to the utmost extent that will add to our information, and although in a sense photomicrography is only an extension of the use of the ordinary camera and lens, the instrumental needs in this field of work are so different that it is convenient to consider it as a separate section of photographic work.

We have seen that in increasing the size of the image given by an ordinary photographic objective we reach a practical limit at a magnification of some four or five diameters. With a microscope working under the more usual conditions, if we decrease the magnification we reach a practical limit at about twenty diameters. These are practical limits; they can both be exceeded until they meet and overlap, but we then suffer the disadvantage of using apparatus under conditions that it is not constructed for, with the consequence that the work done will be inferior in quality. This difficulty of getting good results with magnifications from about five to twenty diameters, is now quite overcome by the introduction of special lenses, which can hardly be called microscope objectives because they are not suitable for use with eyepieces, though they are generally used in conjunction with a

microscope stand because of the convenience that this affords for their manipulation.

Photomicrography, as its name implies, is the application of photography to microscopical purposes. It is probably the first use that photography was put to, for Thomas Wedgwood photographed the images given by a solar microscope more than a hundred years ago, and some forty years after this Herschel and Reade worked in the same direction. The solar microscope was an ordinary microscope through which direct sunshine was reflected, and the image produced was received upon a sheet, after the manner of the image produced by an optical (or "magic") lantern. But all these experiments were very crude, for the microscope then was little more than a toy when compared with the perfected instrument as we know it, and photography was in its earliest stages.

We have already seen that the ordinary photographic lens differs from the microscope objective. The first is intended to give a comparatively small image of a distant object, or if the object is nearer an image that may equal it in size or is at the most a little larger than the object. The microscope objective deals with small objects which are brought very near to it, and has to give a large image. But this is not the only difference, for the image in the camera is taken just as the lens produces it, while the image in a microscope must be so perfect that it will stand magnification by the eyepiece and still appear well defined. In the construction of an ordinary photographic lens the comparative perfection of the image is obtained by correcting its aberrations, the nature of which we have already discussed; but in a microscope objective this is not sufficient, for we are here getting towards the absolute power of the lens, the defining power, that is,

of any lens under the given conditions, assuming it to be entirely free from all aberrations.

The power of a lens to give an image showing minute detail is called resolving power, because it is expressed by the minimum distance apart of two points which the lens is able to show as two separate points. Two points closer than this would be shown unresolved or unseparated and would be indistinguishable from a single point. It might be thought that this power would depend simply upon magnifying power, but that is not so. Simple magnifying power concerns the eye and its ability to see that the two points are separated in the image, rather than the actual fact of their separation by the lens that produces the image. Whatever eyepiece is used in the microscope the resolving power of the objective remains unchanged. The eyepiece only magnifies the image produced by the objective and enables one to see it better. Some people who are blessed with exceptionally good eyesight will require only a small magnification of the image to enable them to see all that there is to be seen, while others will require a greater degree of magnification to make up for their want of keenness of vision. As the resolving power of an objective is a fixed quantity and does not depend upon its magnifying power, the question is, upon what does it depend? Obviously the aberrations or faults of the lens may reduce its power in this direction, but if it were possible to make a faultless lens, its resolving power would still be strictly limited, because even such a lens would not give an absolute point in the image to correspond with a point in the object. The best that it can do is to give a little disc instead of a point. This disc may be so small that it may appear to our eyes to be a mere point even when magnified ten, twenty, and sometimes thirty diameters, but it only wants a little

more magnification to show that it really is a disc and not a point.

Thus every point of the object is represented by a disc in the image, and the smaller these discs are the more able is the objective to separate or resolve fine detail. Why an ideally perfect lens would always spread out or thicken in the image the detail of the object we cannot explain here, because the discussion of this matter would lead us too far away from our subject, but we must know upon what it depends. It depends upon the light gathering power of the lens: not the brilliancy of the light, but the power of the lens to gather what light there is. We may suppose that every little point of an illuminated or shining object gives out light in all directions, or if on a flat surface, in all directions into the space bounded by the surface. The greater the angle of this light that the lens can receive and transmit to form the image, the smaller will be the spreading or thickening of the details represented, and the higher will be the resolving power of the objective.

The limit to resolving power beyond which with our present means we cannot go, sets a practical limit to useful magnification. If we can see clearly all that there is in the image that the lens produces, further magnification can show us no more and is obviously useless. There is no difficulty whatever in getting further magnification, and if the photomicrograph is to be put up on a wall and examined by a class at a considerable distance, it may be well to make it large, but that is a simple case of enlarging and not a matter of photomicrography. With a magnification of from one to two thousand diameters, we have reached the limit of present-day microscopical work, because an average human eye can then see all that there is in the best defined image that

it is possible to produce. This means that, if there were points or lines side by side so close that it would require 100,000 to 150,000 (using round figures) of them to fill a space an inch long, they would be shown as separate points or lines. It is not easy to imagine what 100,000 to the inch really means. If you were to make a straight row of halfpennies each touching the one next it, and were to continue making this row until it was two miles long, you would then have rather more than 125,000 halfpennies. If now you can imagine these halfpennies to shrink, every one equally and still remain touching each other, the row would get shorter. When the coins had shrunk so much that the whole of the two miles of them had shrunk into the distance occupied by only one halfpenny, they would then be so close that our utmost microscope power would only just be able to show them to us as separate things.

We have given in round figures the inferior and the superior limits of ordinary microscopy, but the great bulk of the subjects that need investigation by microscopical methods are best treated by intermediate magnifications. We need no magnification in order to count the legs of a house-fly, but if we wish to see the minute hairs on its tongue we need a magnification of two to three hundred diameters. We can magnify them more than this, but nothing will be gained by doing so, for they will merely appear larger. Indeed there is a positive drawback to useless magnification in many cases where the object is not quite flat, because if other matters are duly proportioned, those parts of the object that are not exactly in focus will be less clearly defined with the greater than with the less magnification.

In photomicrography what is commonly called a microscope is used, more correctly a microscope stand. The stand carries the objective, and if the eyepiece is

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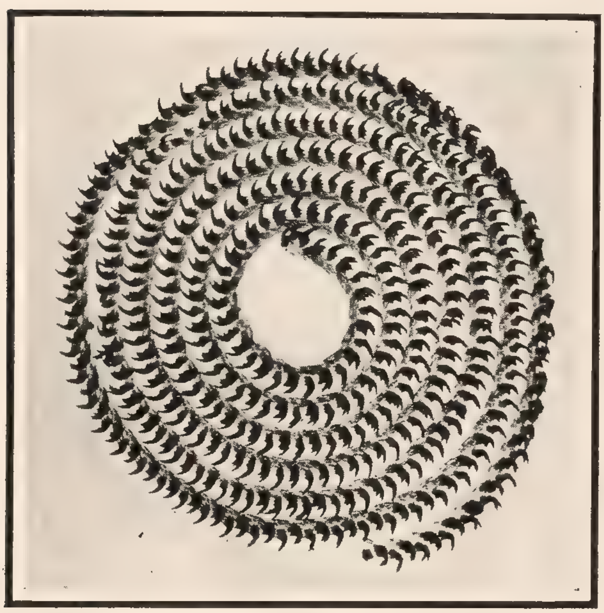
PHOTOMICROGRAPH OF TEETH AND MOUTH OF MEDICINAL LEECH



Arthur E. Smith

PHOTOMICROGRAPH OF PALATE OF LIMPET

replaced by an arrangement to carry the plate, then the apparatus becomes the equivalent of an ordinary camera, that is a dark chamber with the lens that gives the image at one end and the plate to receive it at the other. The stand, however, has to carry the object as well, for the distance between it and the objective is often so small that the very nicest adjustment is necessary in regulating this; and it would be hopeless to attempt to do this focussing unless they were both supported rigidly on the same stand with suitable power of adjustment. But so far we have only imitated the ordinary camera. The essential difference between ordinary camera work and photomicrography does not consist in the simple matter of enlargement, but in the arrangement of the light that falls upon the subject. The majority of the objects as prepared for microscopical examination are transparent and the light is allowed to pass through them, and as light passing through a stained glass window enables the observer within the building to see the design, so the light renders visible or photographable the object on the stage of the microscope. But the regulation of this light has a great deal to do with determining what is visible of the object and whether what is seen or photographed truly represents the thing itself. It must suffice here to say that the light that passes through the object is regulated with the utmost care by systems of lenses that are often made with almost as much precision as the objectives themselves. In spite of all this care and years of study there are some well-known objects the characters of which remain unsettled, because by altering the optical arrangements just a little the image produced changes, and it is a matter of opinion as to which of several images is the one that shows the exact nature of the object. This applies chiefly to high power work, and one example will

show the kind of difference of opinion that may exist. The podura is a small insect found in damp cellars, and minute scales may easily be detached from it. These scales show markings, and it is a matter of opinion whether these markings are like exclamation marks (!) without the dot at the bottom, like French nails or pins, or triangular like cuneiform symbols. The same markings can be photographed so as to appear like either of these, and in each case the image will appear equally well defined.

The difficulty with regard to exceedingly small details arises from the fact that their size is comparable to the length of a light wave, and when such small things interfere with the progress of waves, the effect is not quite the same as the effect of larger bodies, as indeed we might expect. If it were possible to have a row of opaque particles getting regularly smaller and smaller when passing along the row, it would be found, under any given microscopical conditions, that the image of each particle that we could either see or photograph would get smaller as the particles were smaller, the size of the image corresponding to the size of the particle, down to a certain particle. Beyond this the image of each would be of the same size but gradually become less black as the particles were smaller, until the image faded into invisibility, and the still smaller particles would not reveal their presence in any way. By using an objective of the greatest light-gathering power, we could find the smallest particle that the microscope can show the shape and size of, or, in ordinary language, can be seen, and all the particles smaller than this would be termed "ultramicroscopic." If now the light that shines into the microscope were removed, and the particles were illuminated by a light that shines upon them but not into the instrument itself,

we should get a similar result to that described above but the particles would appear bright on a dark ground. It would be possible now to use an extremely bright light and to concentrate it upon the particles, because there would be no fear of hurting the eye or spoiling the photographic plate by an excess of light, for the only light that passes to the eyepiece is that small amount that the particles themselves reflect. There would be the same uniformity of size of the discs of light that represent the ultramicroscopic particles as before, but particles too small to be visible under the previous conditions can now be recognised, and the brighter the light the smaller is the particle that can be seen by its shining. This is the principle of "ultramicroscopy," a method of work that has become of great importance during the last few years. It is important to remember that ultramicroscopy cannot reveal the shape of a small particle, it only shows the presence of it as a point or, if much magnified, a disc of light.

The methods of "dark ground" illumination are useful for larger objects than the particles that we have just been discussing, in fact for magnifications down to the smallest, and are of special use for objects that are very transparent, so that they, or parts of them, are scarcely visible when the light is allowed to pass through them into the microscope in the more usual way.

The object of photomicrography is to represent the nature and the structure of the things that it deals with. In biological work it is customary to apply stains to the preparations, because by their means some parts will be coloured, while other parts which are of a different character will not become coloured or will be coloured differently, and thus the structure of the object is rendered more obvious. Some objects, such as minute organisms,

are so transparent that they are almost invisible, and they are stained to make them more easily seen. Sometimes it would be well if the stained parts were more deeply coloured, and perhaps sometimes the colour is so dark that it hides the detail in the parts that it is desired to emphasise. In photomicrography any colour can be made to appear lighter or darker at will, and it is thus possible to produce a photograph that is better than the original for the purpose for which the preparation was made. If, for example, the stain is blue, it may be made to appear black by using a deep yellow, orange, or red light, for blue is blue because of its power to absorb these colours from white light, and if light of only these colours is used, the blue absorbs all the light that there is, and the effect is the same as if the light were white and the stain black. But if blue light is used, then the blue stain will allow this to pass as readily as the colourless parts, and the effect of the stain is done away with. By such methods as these the effect of the colour may be controlled to any desired extent.

But there is another and quite distinct effect of colour. We have seen that there is a certain minimum size of particle that is visible or photographable under any fixed set of conditions. We have seen also that this depends upon the light-gathering power of the objective, and we add now that it depends also upon the wave length of the light used; the shorter the wave the smaller the particle that any given objective can give an image of. Here, therefore, after having got the most powerful objective from the light-gathering aspect, we have a means of pushing our results further into the realm of the excessively minute. The wave length decreases as we pass from red to green and from green to blue and violet, and goes on decreasing as we pass into and further into the

ultra-violet, Blue to the eye is dark, violet very dark, and the ultra-violet gives no visible effect, so that in this direction we are soon stopped in our visual observations. But the photographic plate is strongly affected by the violet and ultra-violet, and by its means, therefore, we can use light of far shorter wave lengths than our eye can recognise, and though the image so obtained, with its much finer detail, is invisible, it can be photographed, and in this sense we can photograph what we cannot see and can never hope to see. By the means at present available in this direction, it is possible to get a photographic image of a particle that is little more than half the diameter of the smallest particle that can be seen by ordinary light, and this means a corresponding increase in the separating or detail-giving power in the case of ordinary objects.

We have so far spoken of transparent or partially transparent objects, but opaque objects are also subject to investigation by photomicrographic methods, and the difference is only a matter of getting them suitably illuminated. One of the most important of the applications of this method of work is called "metallography," and it has become almost a separate art. The methods of testing metals and alloys used to be merely to ascertain the proportions of their constituents and certain facts concerning them, such as the maximum weight that a wire of known size could support, their brittleness, and other such properties. Now it is usual to supplement these tests by polishing a surface of the material, subjecting it to a liquid that has a feeble solvent action on it, and then making a photomicrograph of the surface. The solvent or etching liquid never acts evenly over the surface treated, because no metal or alloy is thoroughly homogeneous. The most readily attackable parts are dissolved away the fastest, and leave the other parts standing up in small relief. But what is generally

of more importance is that corrosion is usually accompanied by a change of colour of the surface corroded, and this is sometimes of a very striking character, as for example when pickles and fruits come in contact with one's dinner knife. By photographing such a prepared surface the nature of the metal or alloy can be ascertained, whether it is fibrous, granular, or crystalline, and further whether it is coarsely or finely granular, whether the crystals are large or small, of one or of several kinds, and so on. This knowledge of the form in which the various parts exist, that is, the structure of the substance, is an exceedingly valuable guide, not only in discovering the character of the material at hand, but as indicating in what direction to work in order to prepare alloys with more useful properties.

But the applications of microscopical methods are not confined to laboratory preparations or lifeless objects. The small living organisms which are to be found almost everywhere, in the air as well as in the water and the earth, can be photographed by means of the microscope. Many of them are in constant movement, and by the use of a sufficiently strong light these can be photographed instantaneously. Indeed the cinematograph can be used in such cases in conjunction with the microscope, and so the actual movements of these minute creatures can be permanently recorded for subsequent demonstration. There is therefore no break in the continuity of the application of photographic methods on account of the size of the object to be studied. The photographer can adapt his apparatus to objects that vary from the inconceivable magnitudes of the heavenly bodies, the landscapes that he can walk over, and the things that he can handle, down to things that are so minute that they are as far beyond our powers of comprehension on the one hand as the

millions of miles that astronomy deals with are on the other.

And the power of control exists not only in the size of the object dealt with but also in the size of the photograph itself. There is a practical limit to the size of photographs taken directly in the camera, especially if glass plates are used, though in extreme cases it is surprising how large the apparatus can be. It is recorded that a negative, and a carbon print on a single sheet of paper, have been made seven feet by four and a half feet, and those who are accustomed to deal with photographs about the size of their hands can get a practical idea of this size by comparing it with their dining-room table. The enthusiasm that would lead an amateur to make a direct negative on a glass plate five feet by three feet is very rare but not unknown. The more usual way of making very large photographs is to get a small negative and from this to produce a large image after the manner of getting pictures on the sheet with an optical lantern. Such an enlarged picture is allowed to fall upon a sheet of sensitive paper, which is afterwards developed by means of suitable apparatus to support it. Among the large prints made many years ago, there was one thirteen feet by seven feet, but this was made in three sections. More recently a bromide print was made nearly forty feet long and five feet wide on a single sheet of paper, by exposing it in six sections to the enlarged images from six separate negatives, but the development of this huge print was done in one operation, the paper being supported on a large rotating drum made for the purpose.

It may be of interest to pass now to the other extreme in the sizes of photographs. The little views, about a twentieth of an inch long, that are sometimes mounted with a globule of glass to magnify them in the ends of

pensticks and other fancy articles, are produced by using a microscope in a reverse direction. The illuminated object is put in the position usually taken by the eye and the sensitive plate takes the ordinary place of the object on the stage of the instrument. In this way a microscopic image is produced, and it is only necessary to take care that the texture of the film is not too coarse, to get on development and fixing a tiny photograph of fine enough detail to stand considerable magnification. This method of "microphotography" became of very great importance in many ways during the Siege of Paris in 1870–71. Pigeons could pass with fair regularity into or out of the city, as they had been trained to do so. But a pigeon can only carry a load of a few grains in weight, twenty or thirty perhaps at the most. By setting up the suitably printed despatches and photographing them on a very small scale on thin collodion films, about a thousand communications could be obtained upon a single pellicle a little larger than three postage stamps. By means of a projection microscope and an arc lamp, an enlarged image of the microscopic news sheet was thrown upon a screen, and the messages were copied and despatched as required. The whole series of despatches transmitted during the siege amounted to about a hundred and fifteen thousand, and as, in order to make sure of safe carriage, the communications were duplicated from twenty to forty times, as many as two and a half millions were photographed and transmitted during the two months of the investment. A single series of the one hundred and fifteen thousand despatches in the form in which they were transmitted, weighed only about thirty grains. M. Dagron, who organised the pigeon post, used a multiple camera with twenty lenses, producing twenty photographs at once, in order to expedite matters.

When we consider into what an exceedingly minute

space it is possible to obtain so much reading matter, we see a possible solution of the difficulty of the growth of our national libraries. Such pellicles would probably be more lasting than the paper used at the present time for newspapers and magazines, and it would be easy to arrange so that the reading of the minute sheets was no more trouble than the looking at pictures in a stereoscope.

CHAPTER XIX

SUNDRY APPLICATIONS OF PHOTOGRAPHY

We have already referred to many of the uses of photography, and to some in considerable detail, though chiefly by way of illustration or because of the intimate connection of the matter with the subject under discussion. As already indicated, it would be absurd to attempt to give anything like a complete survey of photography in its applications, but a few of the more obvious of these, and especially such work as has been rendered possible by photography and would be impossible without it, may well claim attention in connection with our subject.

We naturally turn first to portraiture, for there are persons who still apply the word "photographer" only to those who get their living by making portraits, and it is the portrait photographer who is commonly distinguished as a "professional photographer." Until photography was available for the purpose, portraits were a luxury for the rich, now they are often but little valued by the poor, though no one can estimate the benefit to all classes by the possibility of good and cheap portraiture. The one interfering circumstance in the practice of this branch of the art, from a technical point of view, is the variability of daylight from day to day as well as through the changing seasons, and it was only natural that those whose livelihood depended upon this work should desire some method of replacing daylight by a more constant source of illumination. The first really successful effort in this direction was by Mr. Henry

Van der Weyde, who fitted up a studio in Regent Street, London, from which daylight was excluded. Although electric lighting was at that time (1877) only in its early infancy, he installed a gas-engine and a dynamo, and devised an electric arc lamp that was so satisfactory that it is still in use. The light from the arc did not shine directly upon the sitter, there was a small screen to prevent that, it illuminated the inside of a large umbrella-like reflector that served to moderate its intensity and diffuse it more pleasantly. The whole arrangement was mounted so that it could be easily brought into any desired position.

Since then many kinds of lamps have been constructed for portraiture, and those giving a light of less intensity than the arc, such as incandescent electric, incandescent gas, acetylene, &c., are generally arranged in groups in order that sufficient light may be obtained to keep the exposure necessary down to a second or two. Very few portrait photographers have followed Mr. Van der Weyde in excluding daylight altogether, chiefly perhaps because of the expense; it is more customary to use artificial light only when the daylight fails. But in trade works, that is where all branches of photography are carried on except portraiture and scientific work, it is quite usual now to use only artificial light. This obviates all difficulties with regard to the windows of the room or studio; the light being always the same the exposures can be timed to a nicety, and summer or winter, day or night, the work can be carried on with equal facility.

The portraiture of criminals as systematically done in prisons is not so important a matter now as it used to be, because the identity of prisoners is generally registered or established by means of "finger prints." The ridges of the skin at the ends of the fingers are constant through life. They may be obliterated by accident but they cannot be altered; in this they differ from the outline and general appearance of the face, and are therefore to be preferred

for this purpose. The getting of finger prints has no connection with photography, the finger is merely pressed on an inked surface and then on paper to get the impression, but it is often desirable to make a photographic enlargement of the print for comparing it with others, particularly the prints made accidentally by criminals during their handling of such things as window-panes, metal boxes, or anything with a surface that is susceptible to being marked by dirty, greasy, or perspiring hands.

A portrait is in essence nothing more than a record of the appearance of an individual, whether it serves to identify a criminal, to recall the features of a friend, or to introduce notable men and women to the general public. There are innumerable other interesting things besides the faces of those we know or wish to know, and all are liable to change. How we should be interested in seeing photographs of London and its characters and buildings at the time preceding the great fire—the people at work and at play, as they travelled and as they lived at home! Within the last half century there have been vast alterations in London. Miles of open country have been turned into paved streets, while many houses and streets of historic interest have totally disappeared; and the same is true, in a greater or less degree, of all towns. The coastline in many parts is constantly changing, so that the sites of what were flourishing towns are now a mile or more out at sea, while some old seaports are nearly as far inland. There are many who would like to see pictures of places, people, and fashions as they were long ago, not to satisfy an idle curiosity, but as helps in the study of history and for scientific purposes. Such pictures, however, are comparatively very few, and some are obviously more fanciful than real. We cannot go back to remedy this deficiency, but it is possible to see that our own times are recorded, that those who come after us may not suffer as we do. And indeed no one can tell how soon such pictures may

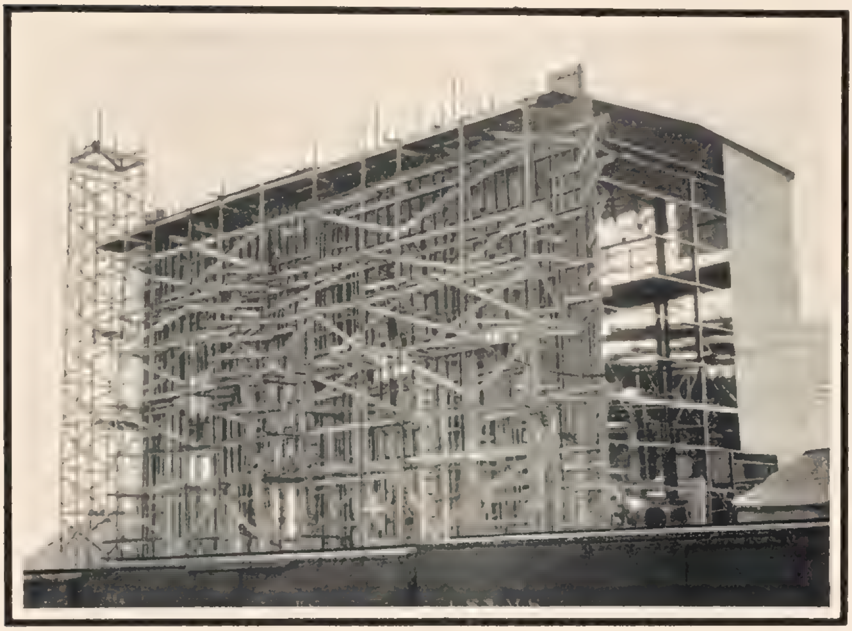
become of value, for sudden disaster may at any time lead to great changes.

The idea of starting and keeping up a pictorial record of things occurred to some archæological societies, and doubtless to others, before the introduction of gelatine dry plates set photography on a new basis. But when photography was popularised by this means, the method that seemed necessary was available, and there was good reason to hope that many amateurs would interest themselves in such work. Mr. W. Jerome Harrison of Birmingham made definite suggestions in 1885 and subsequently, and in 1889 he succeeded in getting the Birmingham Photographic Society to inaugurate a scheme for carrying out a "photographic survey of Warwickshire." A few other societies started work of this kind in different parts of the country, and progress was being made on a rather small scale when, in 1897, Sir J. B. Stone called a meeting to which he invited many persons likely to be interested, and the National Photographic Record Association was established. This association worked for twelve years, not only in collecting photographs, but in seeking to arouse interest in the matter in the many local photographic societies. In 1909, their success in this direction led to the disbanding of the central society that the work might be carried on from various local centres. The National Photographic Record Association accumulated nearly five thousand prints, and these are deposited in the British Museum. The Warwickshire Society has collected some thousands, and the various other societies taken together a few more thousands, and all these are deposited in various museums and public libraries in charge of the local authorities. These photographs represent buildings of interest of all kinds, Roman and other ancient remains, manuscripts, portraits of well-known people, ceremonies, —such as the coronation, customs—such as the dis-

tribution of Maundy money, fairs and May Day celebrations, and other matters that are likely to be of future interest. The method of work is to divide up the district among those willing to assist, and if some have special knowledge the division may extend to the subjects as well; the photographs are made of prescribed sizes and mounted on standard mounts, with all the necessary details concerning the object written on them. Only permanent prints are accepted, such as those made by the platinum and carbon processes. This work is still going on, and there seems no reason to doubt, if it is persevered in, that the historians of a few centuries hence will have much more reliable information as to our manners and customs and surroundings than we have of those that preceded us. By the kindness of Mr. George Scamell we are able to show an example of a series of "street cries" made by Mr. Edgar Scamell, and other illustrations are given showing the nature of such records.

There is a good deal of photographic work done of a somewhat similar kind, though more technical in character and generally for more immediate use. There are many large estates at or near the great centres of industry, on which are a vast number of buildings, some old and some of exceptional interest. In the management of such estates it is constantly necessary to remove houses that they may be replaced by others better adapted to the needs of the present day, and it is not unusual to make a rule of having every building that is to be pulled down or altered, photographed before the changes are begun. And if the property of another owner is close to where an alteration is to be made, it is desirable that photographic records of adjacent buildings be made, for persons have been known to make dishonest claims as to ancient lights, damage done by the disturbance of foundations, and so on. Even if the suggestion of

F. V. T. Lee



F. V. T. Lee

RECORDS OF AN ENGINEERING FIRM

Copies of the actual photographs taken by a firm of engineers as records of work done and the condition of machinery needing repair. The upper photograph shows the corrosion that has taken place in the runner of a turbine. The lower photograph is one of a series taken day by day to show the progress of the erection of a power station. This firm photographs all their work in this manner. The prints are made on post cards, which are filed, as is customary with card indexes.

fraud is entirely dismissed, it is possible for old defects to be brought to light, defects of which the owner had no knowledge and which he honestly considers are due to the disturbances caused by the changes being carried out. A photograph taken before the work was begun may convince him of his error, and so save the cost and the unpleasantness of litigation. It has been stated that in making underground railways, it saves expense to have every building that is likely to be affected photographed before the work is begun.

Although work of this kind cannot be considered as of a very critical character, it is distinctly technical and far removed from what is known as "snapshotting." Indeed a person may be well skilled in some branches of photography and prove unable to carry out such work satisfactorily, just as a person may be able to write beautifully and be a master of language, and utterly fail when confronted with a technical subject. On the other hand, a surveyor who thinks that he has only to buy a camera and follow his instruction book, is comparable to a man who endeavours to translate from a language he knows nothing of by the aid of a dictionary. The photographs, like the translation, may happen to be successful here and there, but they will be almost valueless, for the successes will be indistinguishable from the mass of uncertainties, without independent evidence.

By taking photographs at suitable intervals, and dating and filing them, a complete history of the progress of constructional work in a factory may be obtained in a permanent form. By the kindness of Mr. F. V. T. Lee of California we are able to give an actual example of such a series taken during the erection of a power station. These photographs are not intended to give much detail, but they show the general progress of the building in a more concise, and generally more complete, and obvious manner than any short verbal descriptions could do.

All the work done at this establishment is photographed at suitable intervals, prints are made upon sensitised post-cards, as this obviates the need for mounting them, all the necessary details—description, date, time of day, and photographic particulars—are filled in on a blank form on the back, and the photographs are then put away after the manner of a card index—a far superior method of keeping such records than pasting them in a scrap book, as reference to them is facilitated, and any one may be removed if desired. The pictorial record of work extends also to the condition of machinery received that needs repair, and an example of this is given on the same page as the power station, showing the runner of a turbine and the extensive corrosion that has taken place. If an accident should happen, it would be the duty of those who are available to photograph the scene and its details at once, though nothing would be allowed to stand in the way of rendering immediate aid to anyone suffering from injury. We are assured that this complete system of filing photographic records is of inestimable advantage in engineering works. It is not simply that it provides information that is of use to those connected with the establishment, but it often saves disputes with all their attendant troubles and expense, and if an action at law is unavoidable it provides valuable evidence. By the use of suitable apparatus and films for negatives the time occupied in the making of these photographs is not worth consideration. It is of interest to note that all the engineers employed on this establishment are expected to be able to do this photographic work, just as they are expected to be able to make such written reports as may be necessary.

It is but a step, though a long and important one, from the kind of photography that we have been considering to photogrammetry or photographic surveying, that is the art of preparing photographs that shall

serve the purpose, and from them drawing plans to scale of the country surveyed. It must not be supposed that those whose business it is to draw maps are in any case pledged to depend entirely upon the camera, it is only brought into use when the work can be done better by its means than in any other way. A photographic survey therefore is one done chiefly, but not of necessity entirely, by photographic means. Photography offers the advantage of giving the whole view with its details in a moment, and this may render possible what would be quite impossible by the more usual methods of topograpical surveying. M. E. Deville in a recent report gives an excellent example of this. In 1892 a commission was appointed to study some 600 to 700 miles of the frontier between Alaska and Canada, and to map it, and report within three years. But this district is mountainous and suffers from almost continuous rain and mist. It is impossible to survey by any method when the country to be mapped cannot be seen, but by taking advantage of the bright intervals in the three short summer seasons available, 3000 photographs were taken and a satisfactory map was made. The total area surveyed photographically in Canada is equal to about 25,000 square miles, or an area rather greater than Holland and Belgium put together. Therefore, however much improvement remains to be effected in the application of photography to this purpose, the time is past when it is possible to doubt its applicability and advantages. We are not concerned here with entering into the details of the method employed. It must suffice to say, that the cameras used must be specially constructed so that they may be accurately levelled and in other ways strictly dependable, and that it is desirable to have specially corrected lenses so that distortion may be minimised.

There have been several different cameras designed

to facilitate surveying. Some carry flat plates and therefore represent the view in plane projection. Others have curved plates or films, curved round the lens as a centre, and give the view in cylindric projection. Photographs of the latter kind (panoramic) have the advantage of giving a much greater extent of the view in one direction than is possible with a flat plate, and for that reason the method is sometimes employed for other purposes than surveying. There is a certain point with regard to every lens about which it may be rotated on an axis parallel to its surface, without moving the image that it produces, and the distinguishing feature of a panoramic camera is that the lens swings round on this axis as the exposure is being made, so that the sensitive surface is exposed gradually, as the lens swings, from one end to the other.

Six years after Daguerre published his process, F. v. Martens, a copperplate engraver of Paris, made a panoramic or "traversing" camera to take curved Daguerreotype plates. Fig. 23 is an illustration of this camera taken from the catalogue of George Knight and Sons of that period. It may be noted in passing that the plates for these cameras cost from 4s. 6d. to 17s. each according to size. After this, flat plates were arranged for, by giving them a rolling movement against the curved surface as required for the exposure. When flexible films were made commercially, several cameras of this type were devised, some for surveying purposes, and some such as the "panoram kodak" for general use by amateurs and others. This last camera is of quite simple construction, similar to Marten's, but the lens is rotated by a spring instead of by hand, and there is a chamber at each end to hold the spool of film.

In the method of surveying just referred to the plate is kept strictly vertical, the lens points in a horizontal direction, and the distances of objects are ascertained by

measuring the relative displacement of them in photographs taken from two or more standpoints. But anyone who has viewed the country from an eminence, looking down upon it from the top of a tower or a hill, knows that the bird's-eye view so obtained is a map-like picture of the district. The houses, trees, hedges, and roads, instead of being behind each other as when seen from the level,

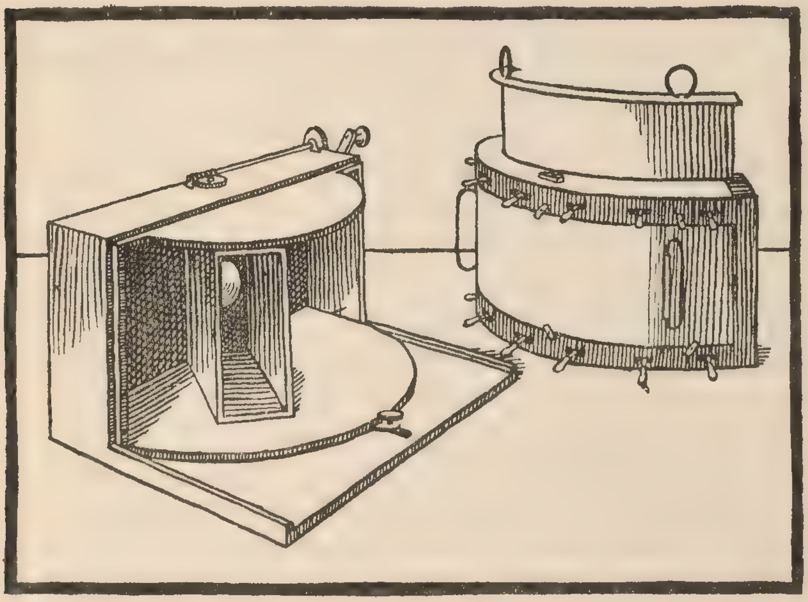


Fig. 23.—The earliest panoramic camera, made by F. v. Martens in 1845.

or a low elevation, are separated so that they can be distinctly identified. Such a view is sometimes exactly what is wanted in military operations, but the tower or the hill is not always at hand, or if an eminence is available it may not be high enough. It is here that the balloon shows its advantages. It appears that M. Nadar was the first to photograph from a balloon, but the results he obtained in 1859 in connection with the war between Italy and Austria were not very satisfactory. But the matter was not allowed to rest, and some quite notable results were subsequently

obtained. The introduction of dry plates greatly facilitated such work, and now the military authorities of all civilised countries recognise the importance of being able to make observations of this character. Cameras have been attached to kites and the shutter released while in mid-air by various contrivances, but although this method is suitable for some purposes, it does not allow of the control and discrimination possible when the photographer himself goes up with the instrument. With the advent of flying machines we may expect to see revolutionary changes in all aerial work, but exactly in what direction these changes will be effected it is impossible to forecast. Meanwhile the photograph of Stonehenge (facing page 188) taken from an aeroplane shows the possibility of such work in spite of the great rate at which flying machines must travel.

It is common enough to photograph the clouds, for almost all out-of-doors views, whether taken for scientific purposes or merely for amusement, include a part of the sky. But it is a well known fact that the sky, including of course the clouds, is very rarely as clearly shown in the photograph as it appears to the eye. This is due to three well understood reasons. If a sufficient exposure has been given for the other part of the view, the sky will have had an excessive exposure, and over exposure, as we have shown in earlier chapters, causes a want of contrast in the picture because the brighter parts do not continue to produce a proportionally increasing effect upon the plate. This can be remedied by making the exposure suitable for the clouds and sacrificing the rest. It will often happen that blue sky and white cloud are hardly distinguishable in the photograph, because of the excessive sensitiveness of the plate to blue. That is, the plate is affected similarly whether, as in the white light from the cloud, the blue is mixed with green and red to give the white, or whether, as in the sky, the blue predominates or is alone. This is remedied by increasing the sensitiveness of the plate

to green and red and using a yellow filter or screen to absorb some of the blue light. The third reason is, that there is always a certain amount of mist in the air due to the small particles in which it abounds and which can be seen in a beam of bright light. These particles reflect or scatter the light according to their size, the larger particles scattering light of a longer wave length. The smallest particles appear to be always present, and it depends upon meteorological conditions as to what extent these are mixed with particles of larger sizes. Rain "clears the air" as we say, washing down these larger particles, and the wind has a considerable effect in distributing them as they rise from fires or whatever smokes or fumes or stirs up dust. Small particles scatter ultra-violet light, rather larger particles scatter blue, larger still the green and then the red. So far as light is scattered by aerial particles, the air is misty, and as photographic plates are sensitive chiefly to the blue and violet and ultra-violet, as the particles increase in size the air becomes misty to the plate before it is misty to our eyes, because the brightest colours to us are green and yellow. So that the air may be misty photographically and clear visually, and it is invariably the case that it is more misty to the plate than to the eye. For this reason all objects at a distance, including clouds, appear in photographs as if seen through a mist, and a denser mist than we can see. This difficulty is remedied by stopping all the ultra-violet and a large portion of the blue, or it may be all the violet and blue, by fixing a suitable deep yellow filter to the lens. By observing these precautions it is possible to photograph clouds with all their detail and intensity and to produce pictures suitable for the study of them, though as they are so constantly and rapidly changing, it is impossible to make fully detailed drawings of them by hand.

The heights of clouds can be measured in different ways. Sometimes they are so low that the upper parts of

high buildings are hidden, or the mountaineer or the aeronaut may pass through them on his upward journey, and then their height can be measured by direct observation. But there may be no building or mountain and no balloon or flying machine at hand, and there may be clouds above the reach of such means, so that these methods are not of general applicability. By photographing them from two points simultaneously, and measuring on the photographs their apparent alteration in position due to the different points of view, their heights can be determined by ordinary trigonometrical methods. The two cameras must be so connected that the shutters of both are released at the same moment, but this arrangement offers no practical difficulty.

There is nothing to be said of a general character as to the photography of rainbows and auroras, and by the use of screen colour plates they can be shown in colour. Photographs of these phenomena are of interest because the opportunities of getting them are so rare. Lightning is also comparatively rare, and the method of photographing its flashes is essentially different from the usual process, because they do not remain for long enough to permit one to focus and expose, or even to expose the plate if the focus has been previously adjusted. It is a mistake, however, to suppose that lightning is an exceedingly rapid effect, for a careful observer will frequently find that after seeing the first glare, he has time to turn his eyes in its direction and to actually see the flash itself. This appears to be due to the multiple character of many flashes. The first discharge is not complete, and a second, third, and even a fourth may take place along the same path, as if the first had made an easier way for the subsequent discharges.

Lightning is photographed at night by pointing the camera towards the direction where it is likely to occur, keeping the lens open. If no flash comes and it is con-

H. H. Hoffert

LIGHTNING

Taken with a camera held in the hand and moving sideways. The three main flashes would be commonly called one flash, and prove that what we see as a single flash may really be multiple. As the camera is moving, each constituent of a multiple flash gives its image on a different part of the plate, because although each passes along the same path, there is an appreciable interval between the passing of one constituent and the next. Other multiple flashes can be seen in this photograph.

sidered that the plate is probably fogged by the general illumination of the sky or perhaps by flashes in other directions, that plate is lost, and another must take its place. As soon as a flash comes in that part of the sky represented in the camera, the lens is covered and the plate removed for development. It is not satisfactory to allow the plate to remain with the lens open with the idea of getting the picture of another flash upon it, because a feeble light gaining access to the plate after the image of the flash has acted on it, is very liable to so affect the plate that the flash is "reversed" and appears as if it had been black instead of bright. To show the multiple character of flashes, the camera, with the lens open, is continually moved from side to side. Each constituent of the flash passes so rapidly that the movement of the camera does not affect the sharpness with which it is depicted upon the plate, but there is a perceptible interval between each constituent and the next, so that the image of the next falls upon a different part of the plate. By the kindness of Dr. H. H. Hoffert we are able to give, facing page 324, a copy of a photograph of lightning taken by him on June 6, 1889, by swinging the camera from side to side as he held it in his hands. It shows the multiple character of at least three separate flashes. The most conspicuous flash is shown to consist of three consecutive discharges, and doubtless there was another before these, the image of which did not fall on the plate. This photograph shows also that the air remains continually luminous, at least in parts, during the intervals between the consecutive discharges which we associate together as a single flash.

It may be asked how is it, if we get three or four distinct images on the plate, we do not see the multiple character of the flash by our eyes, why cannot we see the three or four flashes one after the other? That is, as we have explained before, because we see nothing

for less than about the one-tenth of a second—the impression produced in our eyes remains for that time, and if the second flash comes before the impression of the first has died away, it appears to us to be a continuous effect, and there is no intermittency so far as our eyes are concerned. Although lightning is not a very frequent phenomenon, a great deal has been done to elucidate its character by means of photography.

The consideration of the photography of phenomena in the sky naturally leads us to think of those objects that are far beyond the clouds, beyond even the blue sky, and that range in their places away to distances that it is impossible for the mind of man to conceive of. We may talk of millions of miles, of thousands of millions of miles, and millions of millions of miles, but we cannot comprehend such distances. Anyone who has a camera and knows how to use it can photograph the sun, moon, and stars, but the photographs obtained would be of no use for astronomical purposes. The image of the sun or moon produced by such a lens as is generally used with a half-plate camera would be about the sixteenth of an inch in diameter, and this is far too minute to be of service. The moon and the stars being far inferior to the sun in brightness would require long exposures, and if the camera was fixed they would show as streaks or lines of light because of their apparent movement in the heavens. For practical work therefore we must have a camera and lens that will give a much larger image and that will move constantly and regularly so as to compensate for the earth's rotation. Such an arrangement is an astronomical telescope with the eyepiece removed and a holder for the sensitive plate put in its place. The telescope is kept moving by a specially constructed clock, but although such mechanism is sufficiently good for eye observations, it is not perfect enough to keep the image still upon the plate for the protracted exposures that are sometimes necessary. A smaller

telescope attached to the main instrument has in its eye-piece two fine wires which cross each other, and the observer makes by hand such adjustments as may be necessary to keep the image of the required star exactly on the cross wires.

If a larger image is required, the lens used must have a greater focal length, for the diameter of the image increases exactly in proportion to the focal length of the object glass. And if the focal length is great, the diameter of the lens must be increased also, because we must have more light to produce a larger image if we wish to maintain the brightness of the image. Thus astronomical telescopes are long and large, and the size of the larger instruments is limited only by their cost and the mechanical difficulties of manipulating them. It is easy to see the reason for this with regard to the sun, moon, and planets, which give images of measurable size with the smaller telescopes, but the stars are only points of light to even the largest instruments, and if their images are anything more than absolute points, it is because of the optical phenomena concerned in producing the images and the imperfections of the lens. If then we have mere points of light, what is the use of trying to get a large image? The size of the image in this case is not the image of an individual star, which indeed gives no real *image* at all, but of the little patch of sky that is being dealt with. The larger the image the more space will be shown on the plate between the stars, and this means that two or more stars that are so close that they seem to be joined to form one star when using a small telescope will be separated by a larger instrument. When dealing with objects of small luminosity, such as stars, nebulæ, and comets, the light-gathering power of the telescope, which is represented by the size of the object glass, is of great importance. Doubling its area is equivalent to doubling the luminosity of the object, and thus stars that are not bright enough to

be visible with the smaller telescopes are brought into view, and as it seems probable that the feebler stars are generally less bright than others because of their greater distance, the "penetrating" power is increased with the light-gathering power. Every telescope has its fixed limits in this direction so far as the eye is concerned, for what an observer cannot see, he will not be able to see by looking for a longer time. But in photography this limit disappears, for the plate stores up the effect the feeblest light produces in it, and it is only necessary to prolong the exposure sufficiently to get registered upon it objects that we can never hope to see because they give out so little light. The limit here, therefore, no longer depends upon the telescope directly, but upon the possible increase in the duration of the exposure, or, what is equivalent, increase in the sensitiveness of the plate used.

Astronomers have realised the advantages that photography should offer them from the earliest days of the Daguerreotype, and with the advent of collodion plates and gelatine plates, the applications of photography in this direction have steadily increased until simple eye observations are generally of secondary importance. The images that the largest telescopes give of the planets are small, about perhaps a quarter of an inch in diameter. It is rarely if ever of use to enlarge them because the definition is not good enough. The difficulty here is not so much instrumental, but because of the constant movements of the air and the different temperatures of the various currents and moving masses. As air varies in temperature it varies in density and consequently in refractive power, as may be seen by looking across a chimney top from which hot air is rising, or over a flame, at objects beyond. This moving of the image is often sufficient to make photographic work impossible. Here, therefore, a practical limit to the duration of exposures is often imposed upon the patient astronomer. But in spite

of these and other difficulties Professor Lowell recently stated of photography in connection with Mars, that "the camera has shown itself capable of rising beyond the confirmatory into the discovery stage, for one of the plates was instrumental in the detection of a new canal."

There is one difficulty, which, however, might have been predicted and may in due time be obviated, namely that the image on photographic plates consists of metallic silver, and silver is affected by the atmosphere. The image is not permanent. We see that silver changes by the action of the air when the metal is in mass, as articles for domestic use need constant cleaning to remove the tarnish that disfigures them. When there is on the plate the feeblest deposit that can be seen, as in the images of the least brilliant stars that can under the circumstances affect the plate, we cannot be surprised that the minute amount of metal present should suffer change throughout its whole mass and so lose its visibility, for it seems probable that any change from the blackness of the original deposit must tend towards a loss of density. It is probable also that many astronomers regard photography as a simple mechanical process not worth consideration, and that they do not pay sufficient attention to the work to get as nearly as possible to an image of pure silver in clean gelatine, for any plate in which these conditions are not approximately fulfilled is likely to contain within itself the sources of its deterioration. This is not a matter to be lightly set on one side, for in some cases it has been found that as many as a third of the total number of star images have disappeared within ten years.

In the consideration of lenses we saw that whenever light is bent out of its straight path by passing into a second medium of a different kind, the constituents of light are bent to different degrees, so that the light is separated into its parts, as in the rainbow. This is a difficulty in lenses which has to be overcome as far as possible, but by

taking advantage of this method of analysing light it is often possible to tell the nature of the substance that is luminous, and for this purpose it does not matter whether the light comes from a lamp on the laboratory bench or from a star so far away that its light takes hundreds of years to travel from it to us. By this method of light analysis it is possible to tell, not only the nature of substances that can be made luminous in the laboratory, but also what substances are in the sun, in the stars, and in comets; not in the planets, for they shine only by reflecting the light of the sun, as the moon does.

When light that passes through a small hole, or preferably a slit, is spread out into a band of colours, red, orange, yellow, green, blue, and violet, the result is called a spectrum (see Fig. 5), and the instrument that effects the analysis a spectroscope. A full or continuous spectrum, that is one showing all the colours and with no gaps, is obtained when the light from a white hot, solid, non-volatile substance is examined with a spectroscope. But volatile substances in general give off light of less, often very much less, complexity. The metal thallium, for example, when heated in a flame gives a green light that cannot be decomposed. However much the light is bent, there is the one green line or picture of the slit through which it is admitted to the spectroscope, just as if the light had not been bent at all. This green light is simple and cannot be decomposed, and thallium is the only substance that produces light of exactly this character, and therefore, when such light is obtained we know that thallium is there to produce it. Similarly sodium, one of the constituents of table salt, gives a yellow light, which in the same spectroscope is never bent so much as the green light due to thallium. Most substances give very complex lights when their vapours are made to glow, and their spectra consist of a number of "lines," or images of the slit, separated from each other, and from their number

and positions the substance that gives rise to them can be identified, for no two substances when their vapours are luminous have ever been found to give the same spectrum. In this way we know that the sun and stars contain iron, sodium, calcium (the metal of lime), hydrogen, and numerous other substances of which our earth largely consists. And there are many other applications of this method of light analysis to which we have not space to refer.

In eye observations of spectra it is obvious that we must be limited to light that affects the eye, that is to visible light. But we can photograph not only all the light that is visible, but a great deal more that extends in the spectrum beyond the red at one end and the violet at the other. Photography here, therefore, at the same time that it gives a permanent record that can be measured at leisure, vastly extends the range of the work, and has brought out facts that could never have been known without its aid.

In an ordinary spectroscope there is a narrow slit through which the light from the source passes, so that the constituents may be separated with as much precision as possible and without overlapping. But suppose that there is no slit, and that a flame is coloured with both thallium and sodium at the same time, we can get an image of the flame as easily as of the slit by suitable adjustment of the instrument, and now we shall get a yellow image and a green image, side by side, two coloured images of the flame, the one produced by the yellow light of the sodium and the other by the green light of the thallium. The two lights mixed in the flame are separated as completely as if the metals had been vaporised in two separate flames. Now the sun contains many substances, and by isolating the light from one of them it is possible to photograph the sun by means of that light alone, and so to ascertain the proportional distribution of that particular substance on the surface

of the sun. The sun has been photographed by means of its calcium light, and where that light is bright, there calcium is in large quantity, and where it is dull there it is in smaller quantity.

Another application of photography in spectrum analysis is in detecting double stars that are too close together to show as two distinct stars by the most powerful telescopes ever constructed. This might seem at first a hopeless problem, but the method of attacking it can be made clear by analogy. When a whistling engine or car passes by us, the whistle giving the same note continuously as is usual, the note is quite clearly "lower" as it recedes from us than as it approaches us. It generates sound waves of the same length all the time, but as it approaches us each successive wave starts nearer to us than the preceding wave and so a greater number enter our ear in a given time; and as it goes from us each wave starts farther away from us than the preceding one, and therefore we have fewer in the same time than if the whistle was not moving. As we have said before, our eyes and ears know nothing of what goes on outside them, they are affected only by what goes into them; it is therefore not the length of the sound wave that concerns us, but the number of waves that we receive in a given time, that is the frequency of the impulses. As the sounding whistle approaches us we receive the impulses more rapidly, therefore the note is higher, and as it goes from us we receive them less rapidly and therefore the note is lower than if the whistle were stationary. Exactly the same thing happens with light, and if two stars are rolling round each other, when one is approaching us and the other receding, each line in the spectrum will be doubled, the two new lines being one on each side of the position of the single line that will be seen when both the stars are moving at right angles to the line of vision. The line that is displaced toward

the red end of the spectrum will represent the increased wave length caused by the receding star, and the line displaced towards the blue end, the shortened wave length due to the approaching star. Thus the spectrum line gradually divides, the two lines separate, and they come together again to form one line according to the movement of the stars, and the period of revolution and the rate at which the stars are moving towards us or from us can be calculated from the displacement of the line.

But it is impossible to describe the various applications of photography adequately without writing a treatise on each of the subjects concerned. We must therefore be content with mentioning only a few other subjects with which it is inseparably connected. Stereoscopic views show objects in their full solidity by giving each eye that view of the object that it would receive if the solid object were being looked at. The difference in the view as seen by the two eyes is often very small because the points of view of the two eyes differ by only a little, they are so near to each other. It would be hopeless by hand drawing to represent these differences with any approach to sufficient accuracy, but here photography is perfect. And the stereoscope is not a mere plaything or interesting toy; a stereoscopic view is to a single photograph just the difference between binocular and monocular vision if the photographs are properly made: it reveals the true shape of things, and the comparative distances of things or of their various parts. It is applicable to microscopic objects as well as to larger views, and even the moon has been subjected to similar treatment by photographing it in two different aspects, for a pair of stereoscopic views may be made from the same point, if the object is turned a little so as to present the same appearance that it would have from another point of view. The stereoscopic photographs of the moon

show it as it would appear to an enormous giant with eyes a vast distance apart.

In making observations with scientific instruments it often happens that the field of the instrument is but feebly luminous, and that the adjustments of it alternate with the reading of a scale. The scale must be rather brightly illuminated that its fine divisions may be seen, and the constant changing of the eye from a dull to a bright object not only strains it but may impair the accuracy of the observations. Cameras have been made to photograph the scale whenever a reading is desired, and this not only spares the eye and facilitates the adjustments, but gives a record free from bias or possible misreading. Sixty readings can be recorded on a small plate, so that the expense for photographic materials is negligible. Similarly, cameras have been designed for photographing gas, water, and electric meters, watchmen's clocks, &c., and for the continuous and automatic recording of the readings of meteorological instruments, such as barometers and thermometers.

We began our consideration of this subject by stating that photography is writing or drawing by means of light. We have seen how almost every thing and every movement can be recorded and often investigated by its means, and how it is possible in some cases to deal with and investigate the light itself as well as the objects that the light may illuminate. In leaving light we are really going away from photography, yet we may refer to the use of photographic methods in other connections, for the general method of dealing with photographic plates is the same whether they have been affected by light or by any other force that produces a similar change in them. Light so changes the silver salt of a gelatino-bromide plate that a developer is enabled to remove the bromine and leave the metal silver as direct evidence of the change. The silver salt is rendered amenable to the

action of the developer by other agencies than light. It was by putting a piece of a uranium mineral near to a plate and leaving it there for some time, that it was discovered that the mineral affected the plate, and this led eventually to the discovery of radium. Since then a great many other substances have been found that give out a something, either rays similar to light rays, or gases, or something of the kind, that affect a photographic plate. It seems that so common a substance as potassium, which is the essential constituent of potash, gives out something of this sort. The photographic method of testing for these emanations is not the only method, but it has the great advantage that an exceedingly feeble action may be detected by simply leaving the substance to be tested near to a plate in the dark for the necessary time, and this may be extended as may be necessary, for the action is cumulative. If we compare the millionth of a second, which is sufficient exposure to the light of an electric spark to affect a plate, with the months that may be necessary for a potassium salt to produce a similar change, we get some idea of the extreme feebleness of the potassium compound in this direction and might suppose that it is self-luminous to that extremely small extent. But whatever it is that is given off by potassium salts and substances that act similarly, it will pass through various opaque media, and presumably is not what we generally understand as "light."

It must not be supposed that forces are similar because they can produce one similar effect, and it does not follow that because radium glows and affects a photographic plate as light does, that other forces that affect the plate are comparable to light in a general sense. The Roentgen rays certainly affect the plate and might perhaps be supposed to be a kind of light, but every known kind of energy is able to render the silver bromide less stable and

therefore amenable to the action of the developer. Heat, mechanical force such as pressure, electrical energy, and the contact of substances which appear to act in a chemical way, will all render silver bromide developable under suitable conditions, and it seems not impossible that these effects may eventually be utilised as the action of light has been. One fact to bear in mind is that the relationship between the photographic plate and light is not so exceptional as it used to be thought to be, and that it is possible that we are only on the threshold of the applications of methods that we at present associate almost exclusively with light. But looking at photography even as it is, we do not hesitate to say that the growing importance of it from every point of view, educational, commercial, and scientific, is not realised as it should be, or photography would not be left to a few specialists, and a comparatively large number of those who regard its practice merely as a pastime or an amusement.

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